Hypothesis 2: The plume is a result of the first winter-spring storm after ice-out and represents the resuspension of particulate materials (and associated constituents) that have been stored in the lake as surface sediment "floc" for a distribution of times, during which they have undergone differential diagenesis.

What have we learned so far? (as of 11/99)

- Don't need ice.
- There are spring and fall events and there may be several per season.
- Interannual events can range over an order of magnitude.
- Constituents resuspended from sediment inventory > annual external input.
- Particle transport into sediment depositional basins is complex, but radionuclide tracers look promising.

Results

- Large, basin-scale spatial variation residence time.
- Mesoscale spatial variation (coring).
- Traps clearly illustrate basin-scale impacts.
- BBL tripod providing regional ss:tsm relations.

Future Plans

- Less spatial coverage.
- More time series to hone for residence time.
- Tightly designed sediment-water coupling efforts.
- Develop coupled box models and eventually couple with hydrodynamic modeling.

Reports (9/00)

Sediment resuspension and transport: notes from the tripod program -- Barry M. Lesht

Sediment Resuspension and Transport -- B. Eadie, D. Edgington, B. Lesht, V. Klump, K. Nealson, J. Robbins, and B. Tonner

A study of Organic Contaminants and Water in Conjunction with Episodic Events -- Great Lakes Experiment -- Keri C. Hornbuckle, Sondra Miller (air and water), Gretchen Smith (sediment trap analyses)

Sediment resuspension and transport: radionuclide tracer studies -- J. Val Klump, James T. Waples, David N. Edgington, Kent A. Orlandini, Kim Weckerly, Don Szmania, and Richard A. MacKenzie

Role of Episodic Events in Long-Term Accumulation of Sediments -- John A. Robbins, D. N. Edgington, N. R. Morehead, R. W. Rood, B. J. Eadie, and K. A. Orlandini.

Development of a coupled sediment transport and re-suspension model for Lake - Michigan -- Keith W. Bedford, David Welsh, Philip Chu, Panagiotis Velissariou,Vasilia Velissariou and Yong Guo.

Sediment resuspension and transport: notes from the tripod program

Barry M. Lesht, Environmental Research Division, Argonne National Laboratory

Objectives:

1. Determine threshold criteria for initiation of resuspension of the bottom sediments in the Lake Michigan coastal region associated with episodic events,
2. Estimate the magnitude and direction of the horizontal near-bottom sediment flux during episodic transport events.

Approach:

- An instrumented tripod was deployed at several locations in the southern basin of the lake to make long time-series observations of physical and sedimentological conditions within the benthic boundary layer.
- Tripod measurements include horizontal current velocity, water temperature (2 levels), wave height and period, suspended sediment concentration (2 levels, inferred from beam attenuation), and bottom configuration (digital photography).

Results:

- Spring transport events result from surface-wave induced resuspension of local sediments.
- Resuspension events are not limited to the spring, but occur throughout the year whenever wave conditions exceed critical threshold.
- Horizontal near-bottom sediment flux during events can approach 100 $kg/m^2/day$.
- Simple resuspension models using wave orbital velocity as forcing can simulate events with good accuracy.

Summary of Argonne EEGLE Tripod Deployments

Deployment	Location	Depth	Dates	Data hours	Events
98-1	Wind Point, WI	15m	04/02/98-04/30/98	669.5	4
98-2	Oak Creek, WI	25m	07/23/98-08/24/98	770.5	0
98-3	Oak Creek, WI	25m	10/28/98-12/01/98	815.5	2
99-1	St. Joseph, MI	20m	02/25/99-04/19/99	0.0	-
99-2	St. Joseph, MI	20m	04/20/99-06/01/99	1032.0	1
99-3	South Haven, MI	18m	10/15/99-11/17/99	787.5	5
00-1	Milwaukee, WI	20m	02/28/00-04/18/00	1194.0	4
00-2	Milwaukee, WI	20m	04/19/00-05/16/00	0.0	-

00-3	Milwaukee, WI	20m	05/16/00-06/08/00	0.0	-
00-4	Muskegon, MI	25m	09/12/00- present		

Collaborators:

Hawley (additional tripod measurements), Edgington, Klump, and Waples (sediment characterization), Eadie (trap analysis), and Schwab and Beletsky (transport modeling)

Material Submitted for EEGLE Meeting Workbook

Boundary Layer Tripod – Preliminary Results

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email: bmlesht@anl.gov

The packet contains the following:

1. Summary of the locations and dates of the Argonne tripod deployments

2. Six sets of figures showing the basic data obtained from the deployments along with (for some deployments) figures showing ancillary data and results of preliminary analysis.

   The first figure (denoted "a") in each set shows (1) time series of water depth (uncorrected for atmospheric pressure), horizontal current velocity 0.7 meters above the bottom (mab), water temperature at 1 mab (solid line) and at 10 mab (dashed line for those deployments for which this measurement is available), total suspended material at 0.9 mab (solid line) and at 10 mab (dashed line when available), and the standard deviation of the pressure signal recorded 0.7 mab. This last series represents surface wave height.

   Notes on Figures "a":

   - The water depths are obtained from the absolute pressure and have not yet been corrected for changes in atmospheric pressure.
   - The temperature data during the last half of deployments 98-1 and 98-3 (Figs. 1a and 3a) are incorrect. A corrected version of the data will be submitted to the archive shortly.

- The tripod was tipped over on deployment 99-3 and the current meter data are nominal (Fig 5a).
- The tripod was knocked over by waves during the large storm that occurred on April 7 during deployment 00-1 (Fig 6a). The current meter data are missing from this point on.

The second figure in each set (denoted "b") shows the progressive vector diagram obtained from the current meter data. These diagrams show the hypothetical horizontal trajectories of a water parcel under the assumption that the currents around the tripod are horizontally homogeneous. In essence, these plots are constructed by adding the time series of current vectors end to end. Because the tripod was tipped over and current meter was oriented incorrectly during deployment 99-3, no progressive vector diagram is shown for this deployment.

Three other figures (c, d, and e) are included for deployments 98-1 and 98-3. Figure c shows the calculated horizontal sediment flux past the tripod as a vector time-series. Figure d shows the weather conditions recorded by buoy 45007 during the deployment. Figure e shows time series of the calculated wave orbital velocity and wave-current bottom shear stress along with total suspended material and horizontal current speed.

3. Abstract of a paper presented at the 43rd Conference on Great Lakes Research in which we discuss the relationship between sediment transport models and tripod observations.

4. The slides we used in the IAGLR presentation showing that simple empirical models can reproduce the observed near bottom sediment concentration with good accuracy.

Table 1. Summary of Argonne Tripod Deployments in EEGLE (see map on packet page 30.)

No	Deploy	Retrieve	Lat	Long	Depth	Location	Samples
98-1	04/02/98	04/30/98	42 39.9	87 44.9	15	Wind Point	1339
98-2	07/23/98	08/24/98	42 52.2	87 42.4	25	Oak Creek	1539
98-3	10/28/98	12/01/98	42 52.2	87 42.4	25	Oak Creek	1631
99-1	02/25/99	04/19/99	42 12.5	86 27.7	20	St. Joseph	0
99-2	04/20/99	06/01/99	42.12.5	86 27.7	20	St. Joseph	2064
99-3	10/15/99	11/17/99	42 24.6	86 19.5	18	South Haven	1575
00-1	02/28/00	04/18/00	43 05.6	87 50.9	20	Milwaukee	2388
00-2	04/19/00	05/16/00	43 05.6	87 50.9	20	Milwaukee	0
00-3	05/16/00	06/08/00	43 05.6	87 50.9	20	Milwaukee	0
00-4	09/14/00	planned deployment			25	Muskegon	

Figure 1a. Basic data collected during deployment 98-1.

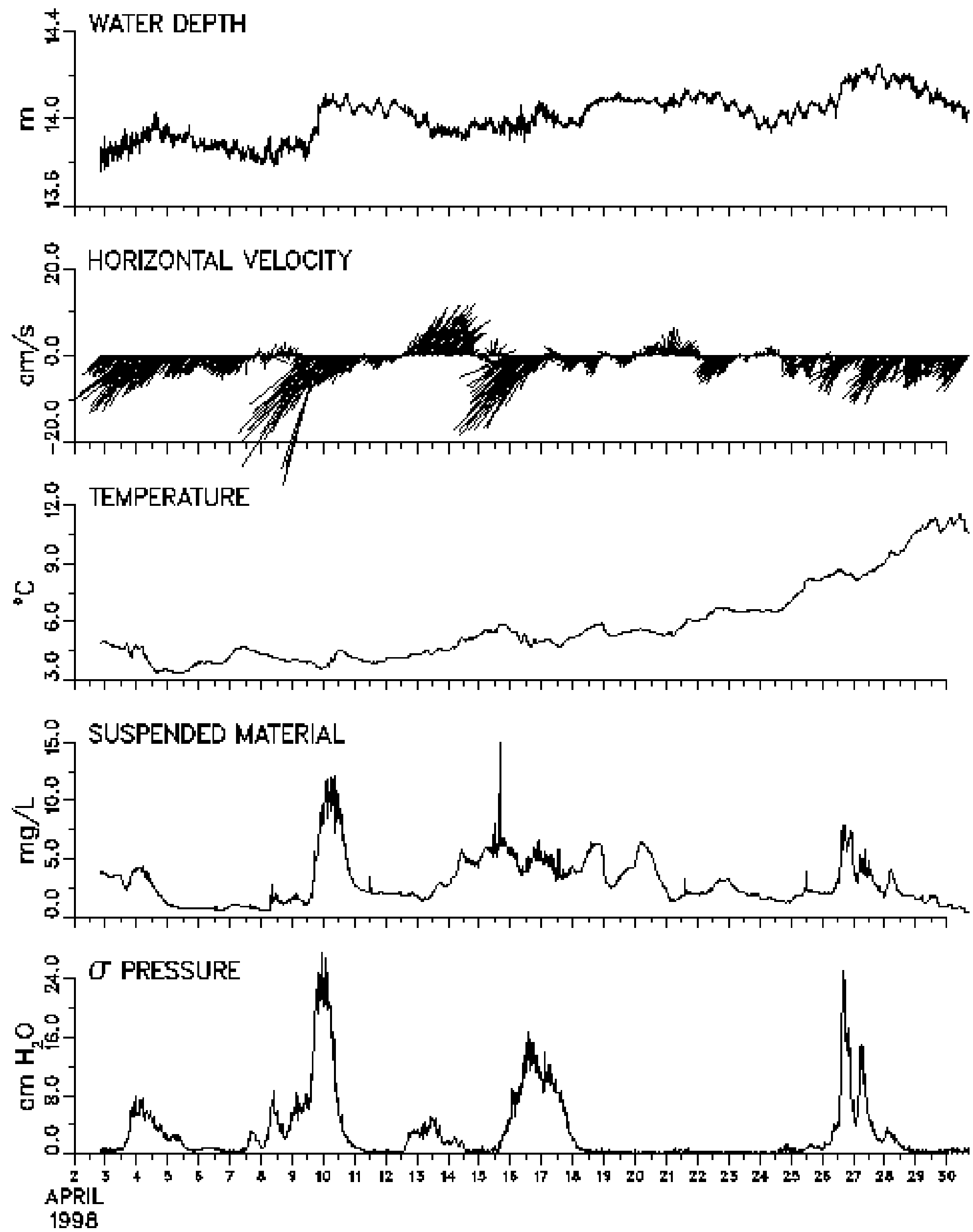


Figure 1b. Progressive vector plot for deployment 98-1

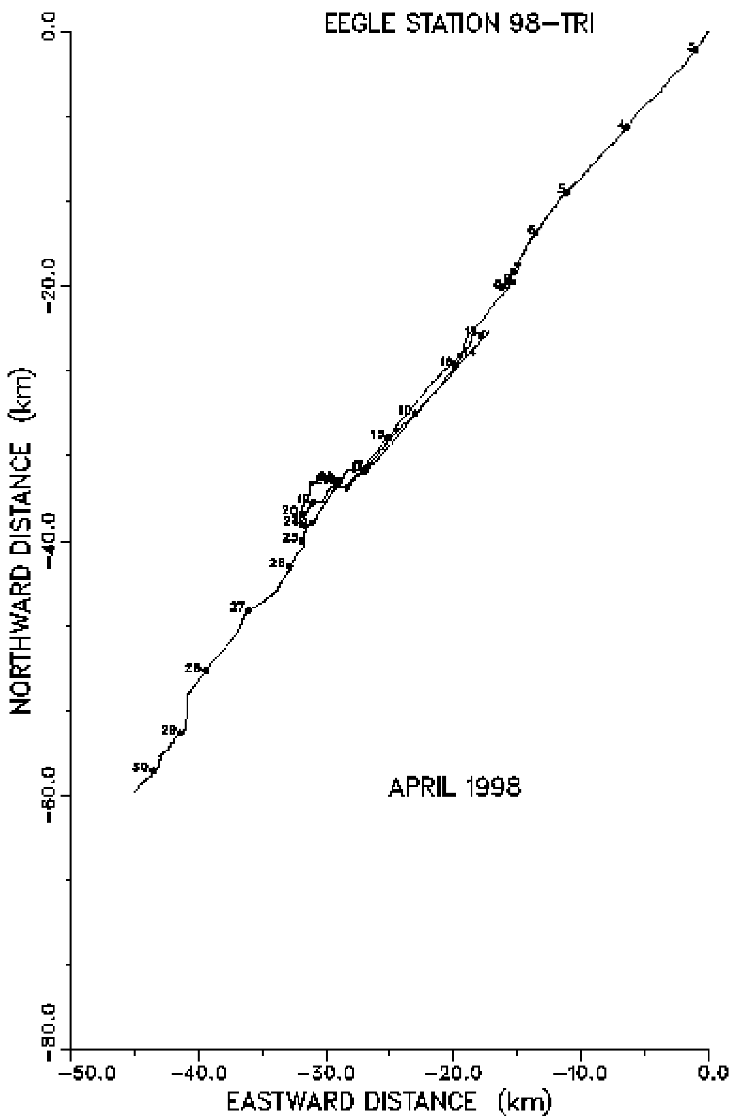


Figure 1c. Horizontal sediment flux observed during deployment 98-1.

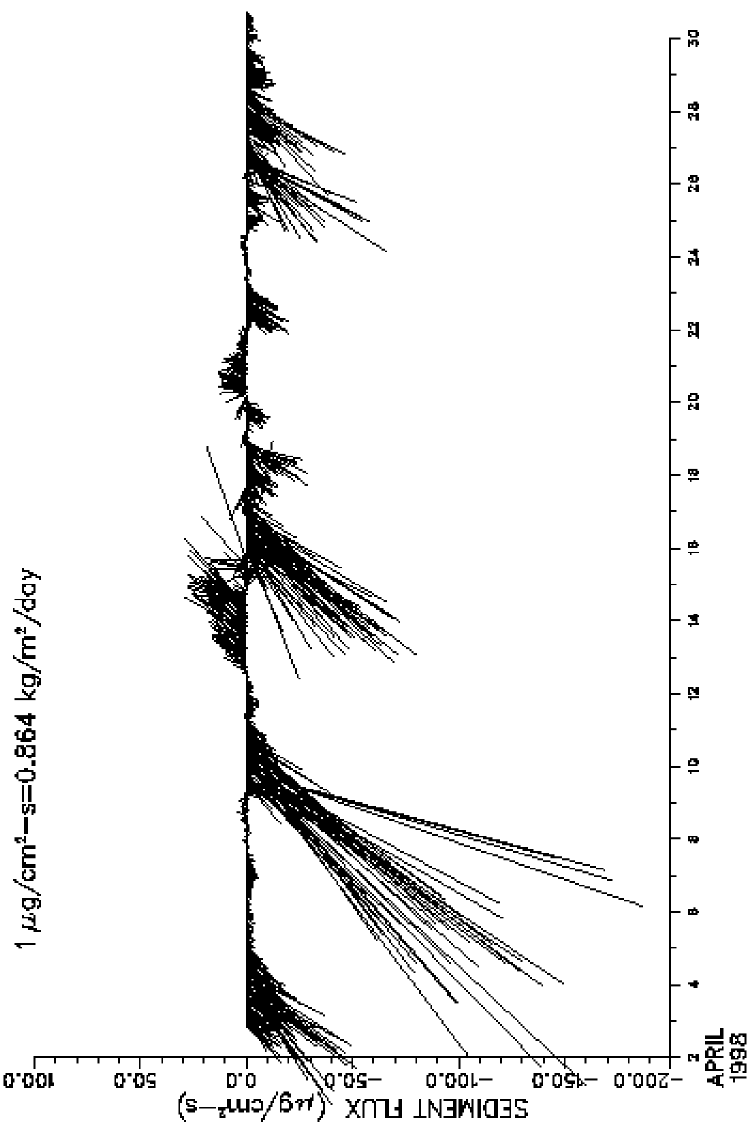


Figure 1d. Meteorological conditions during deployment 98-1.

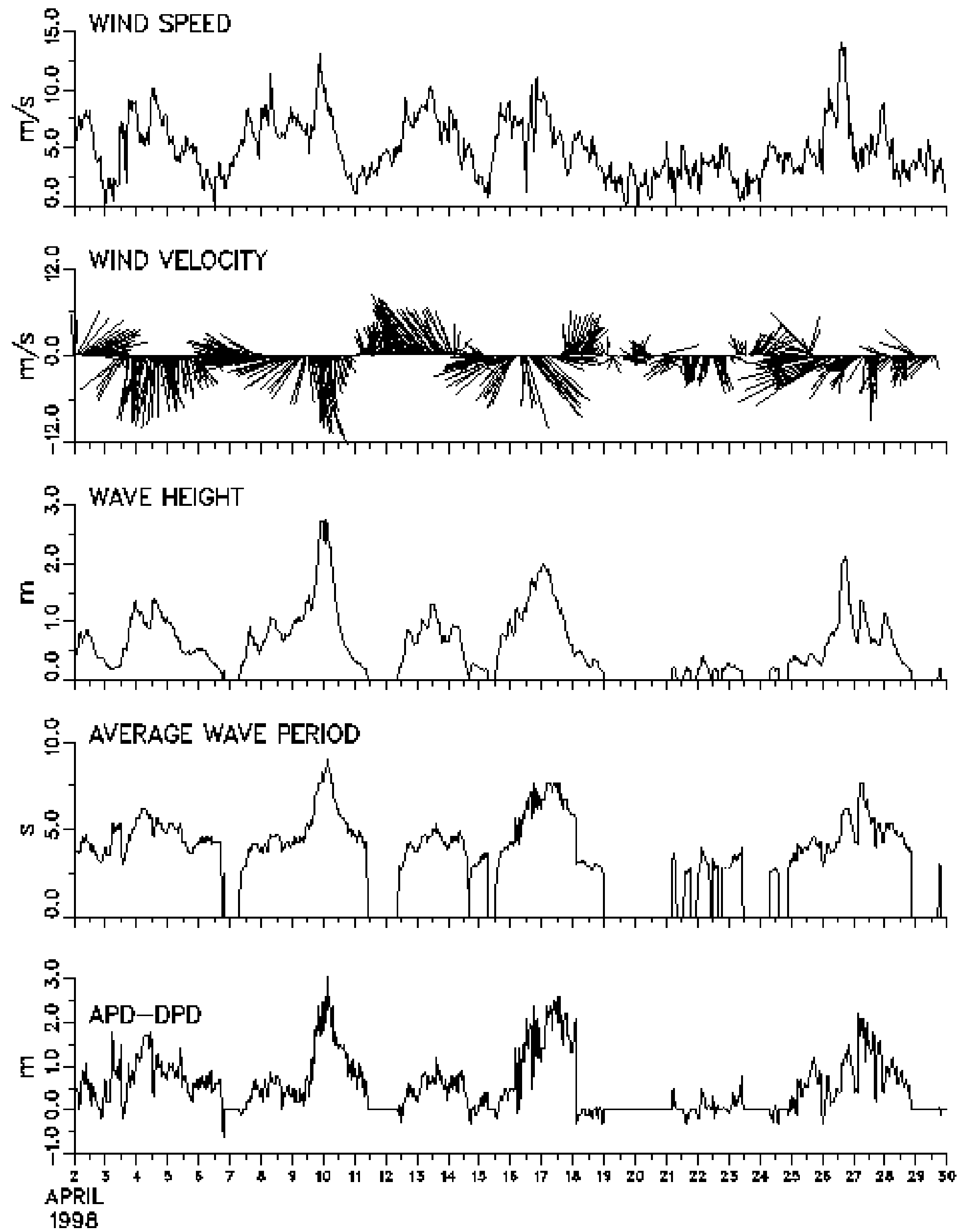


Figure 1e. Near bottom current decomposition and estimated bottom shear stress for 98-1.

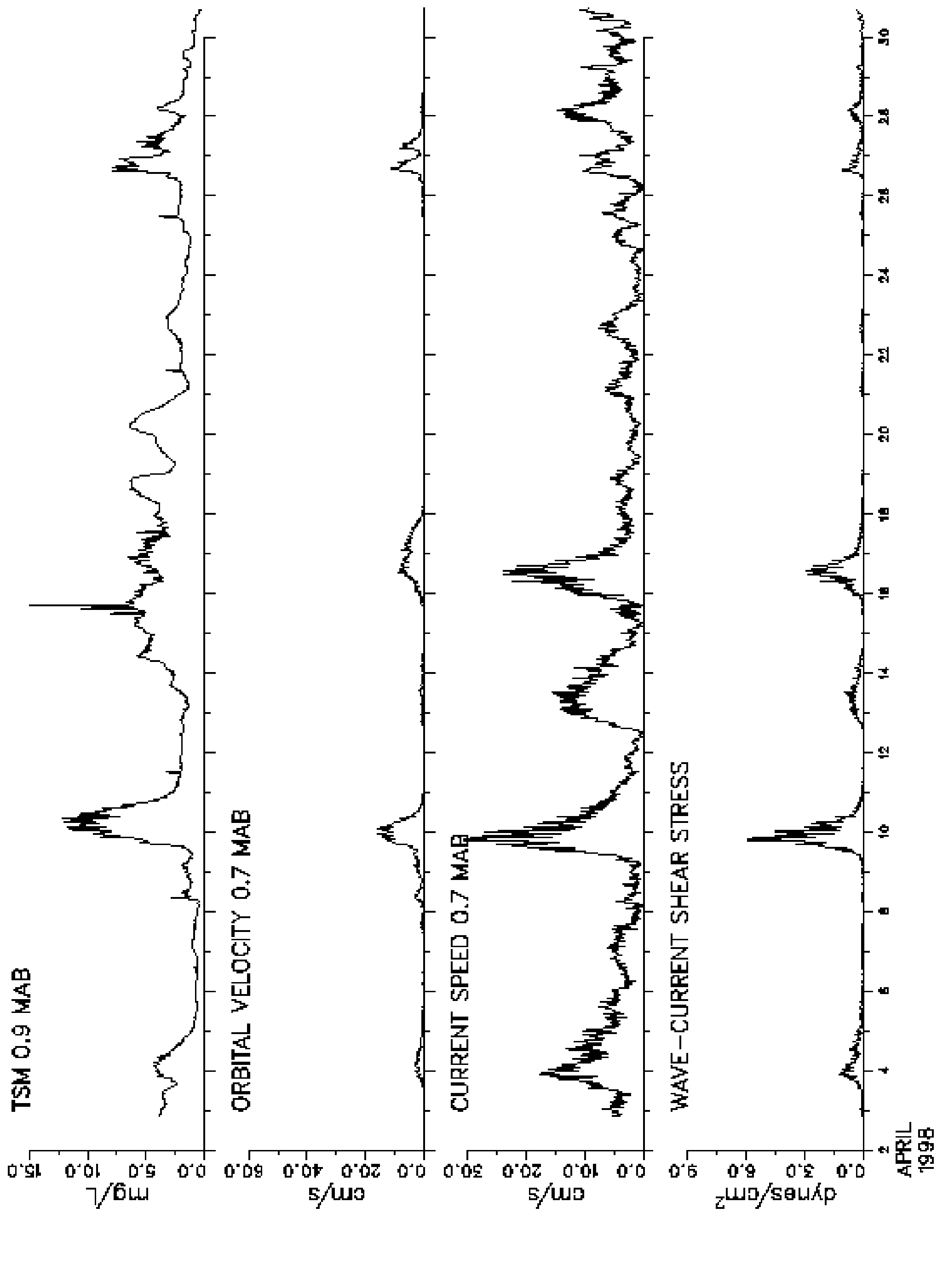


Figure 2a. As in Figure 1a for deployment 98-2.

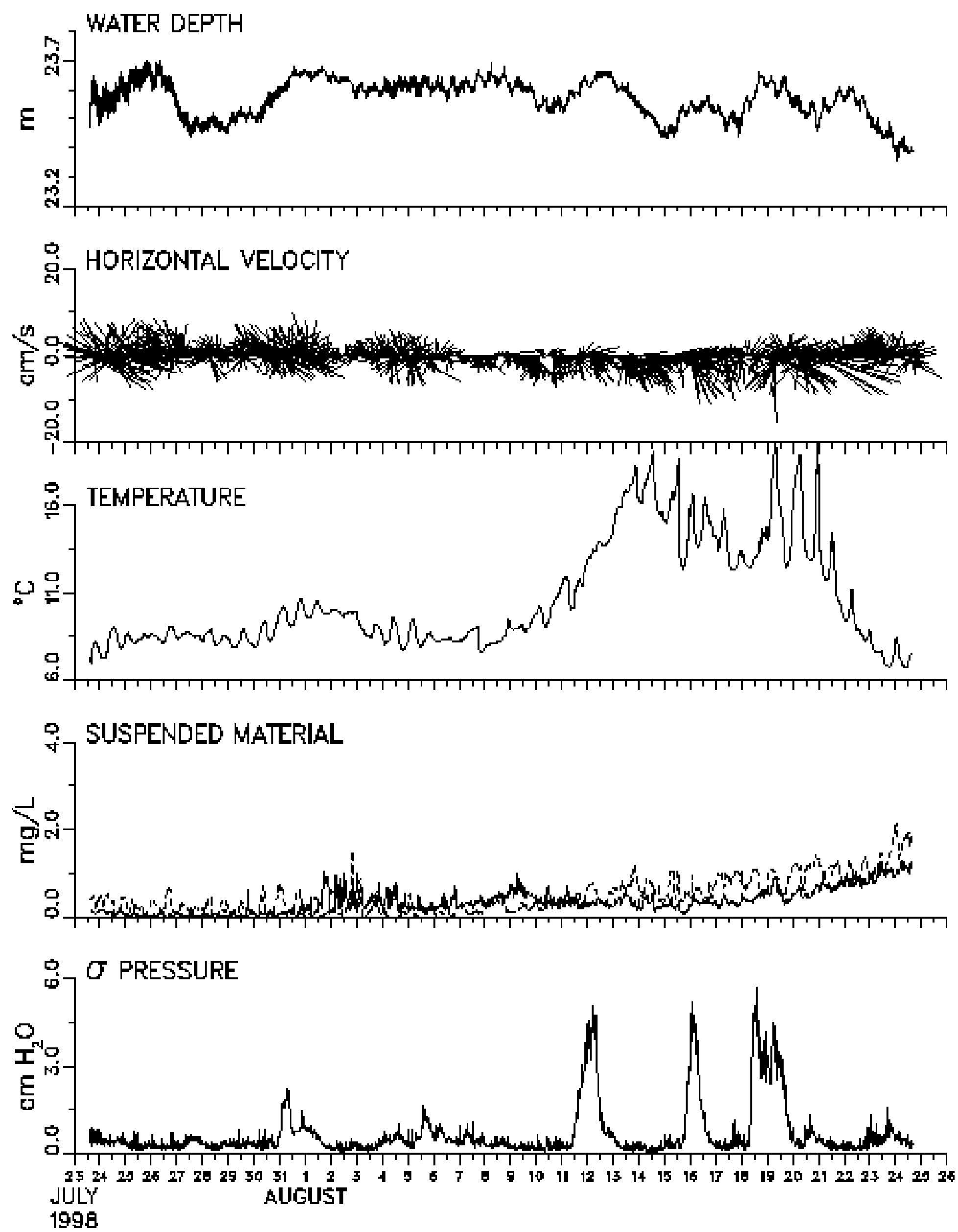


Figure 2b. As in Figure 1b for deployment 98-2

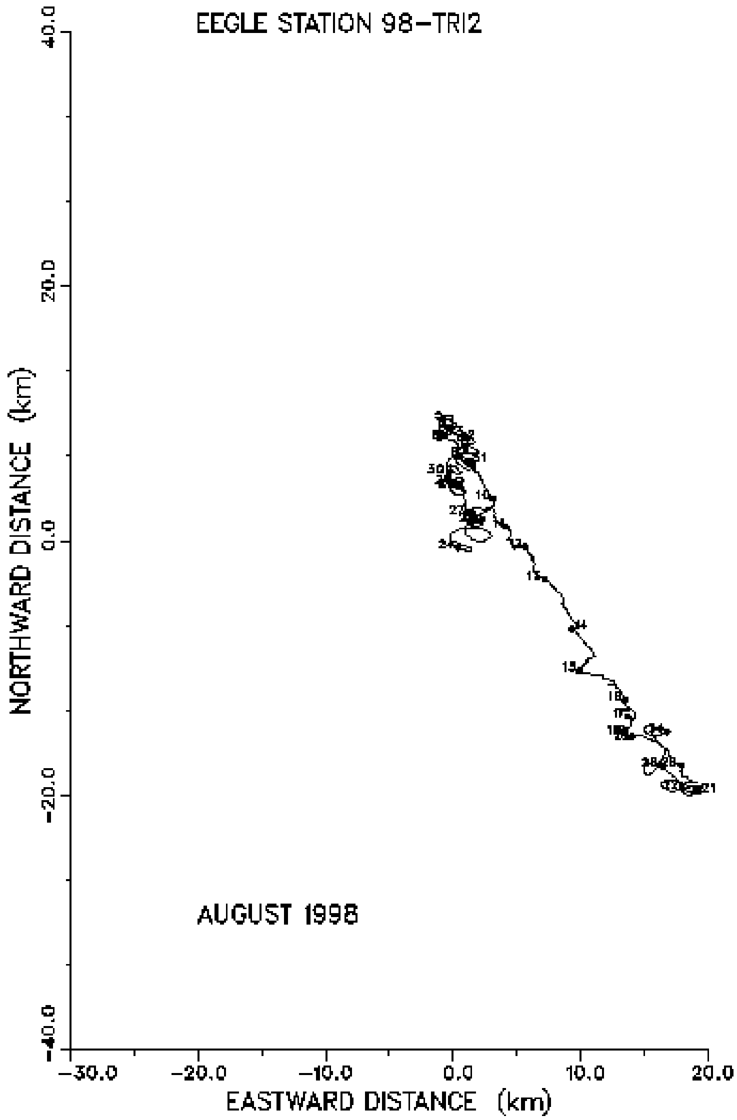


Figure 3a. As in Figure1a for deployment 98-3.

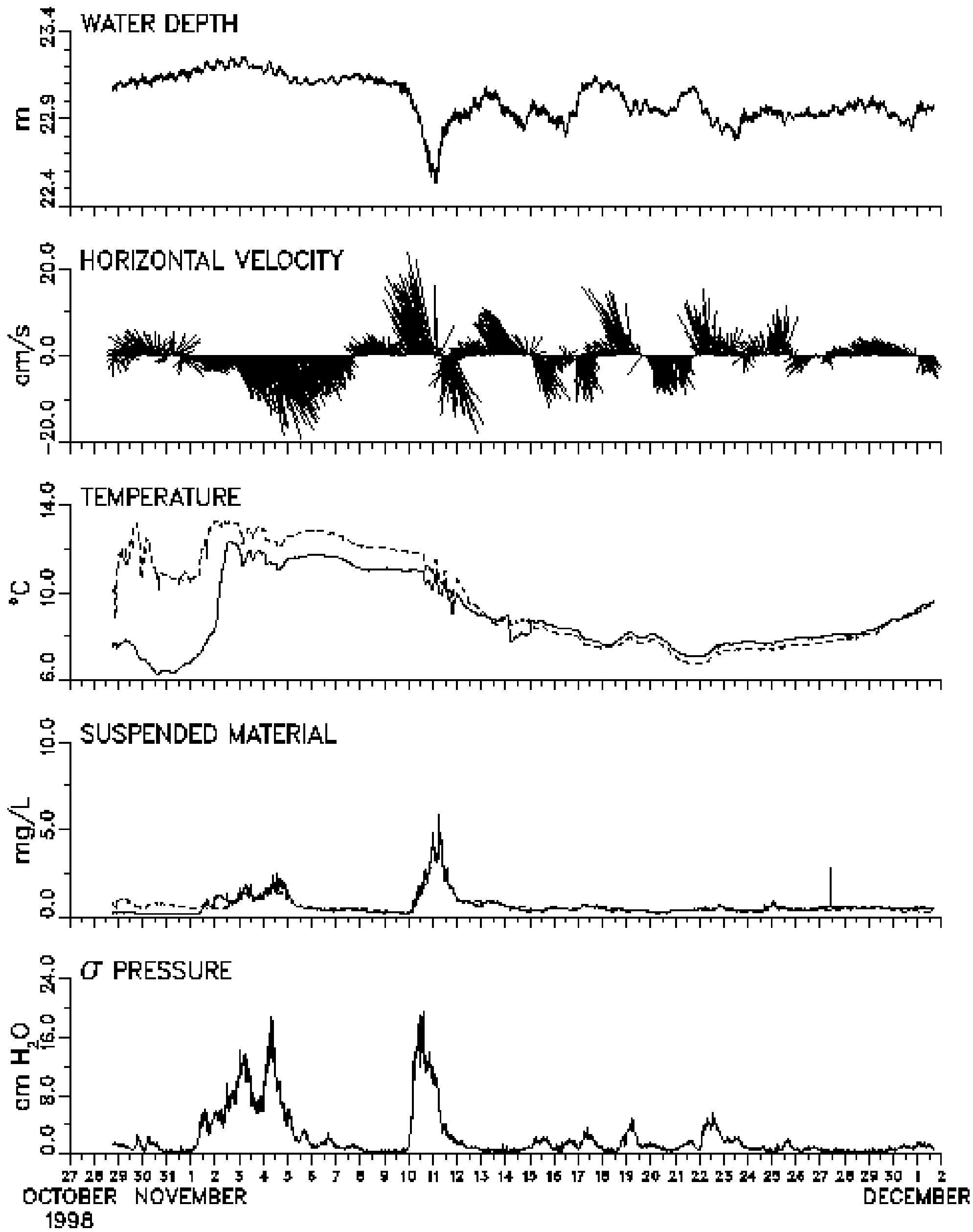


Figure 3c. As in Figure 1c for deployment 98-3.

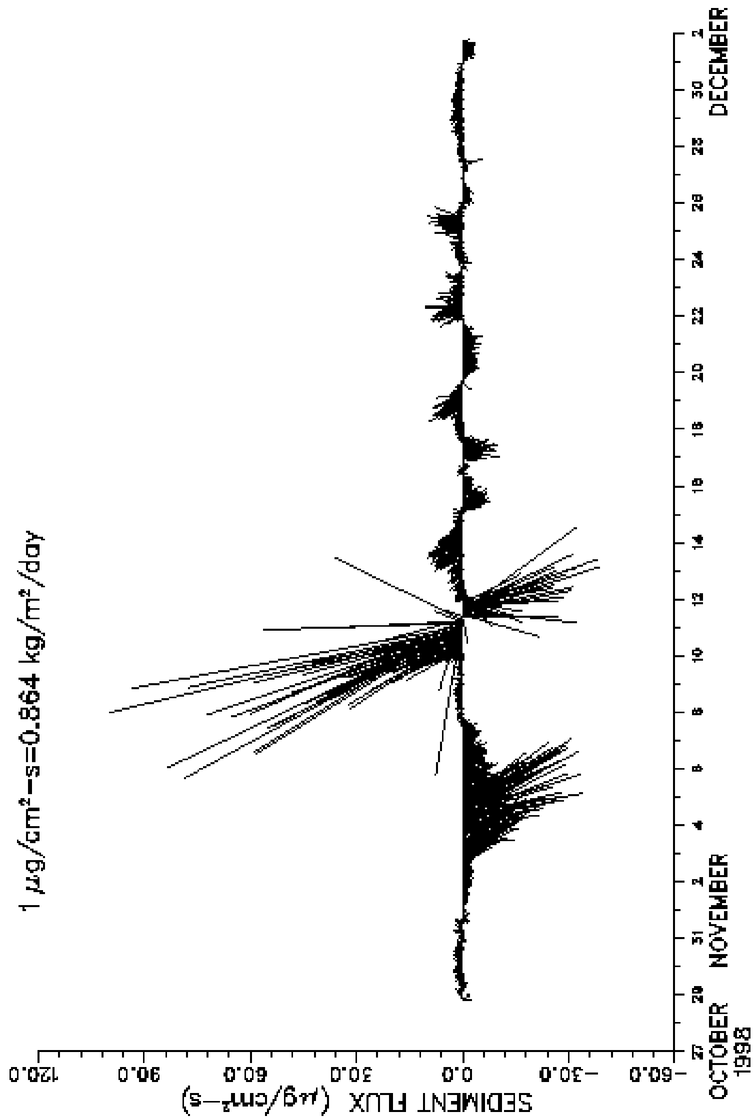


Figure 3d. As in Figure 1d for deployment 98-3.

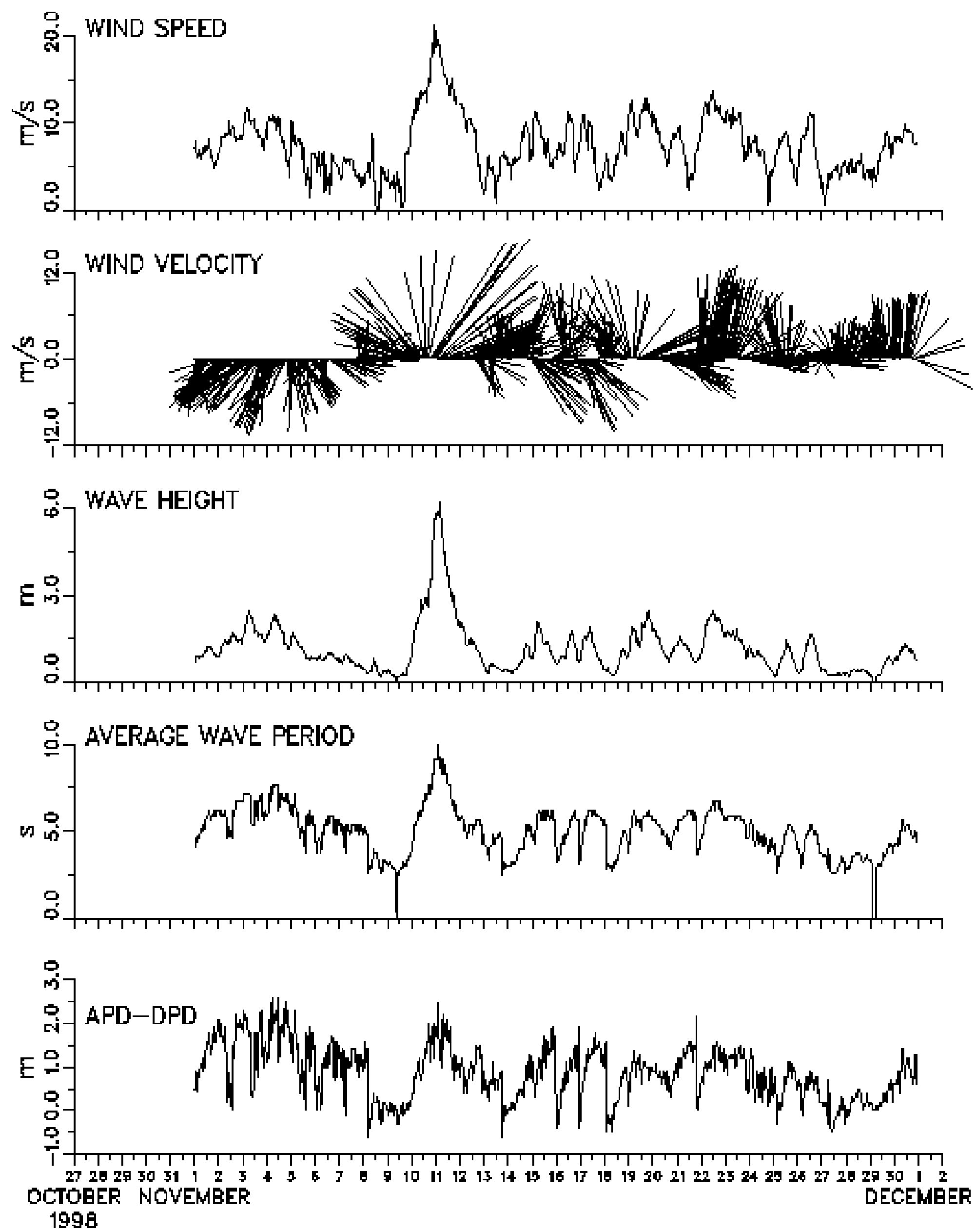


Figure 3e. As in Figure 1e for deployment 98-3.

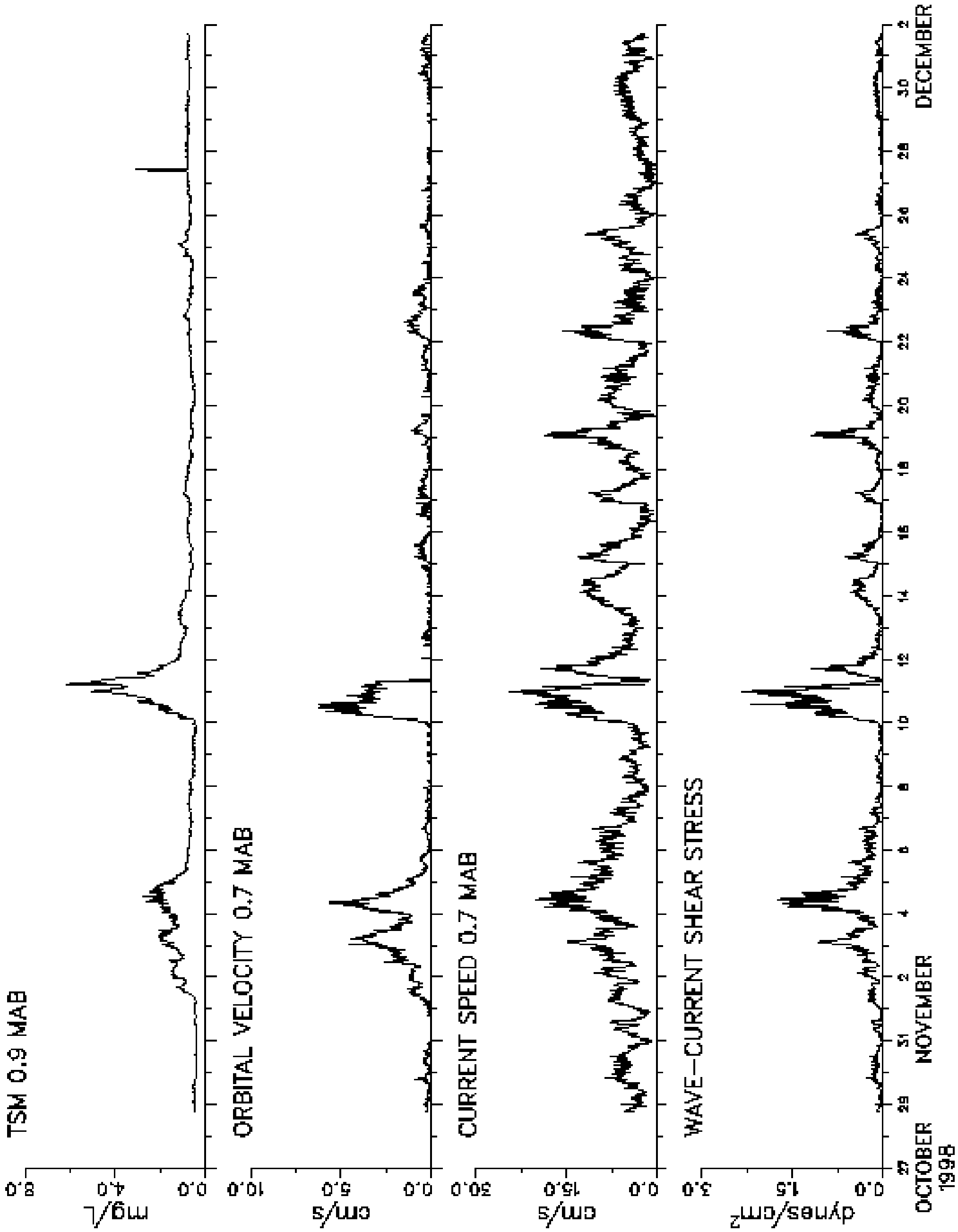


Figure 4a. As in Figure 1a for deployment 99-2.

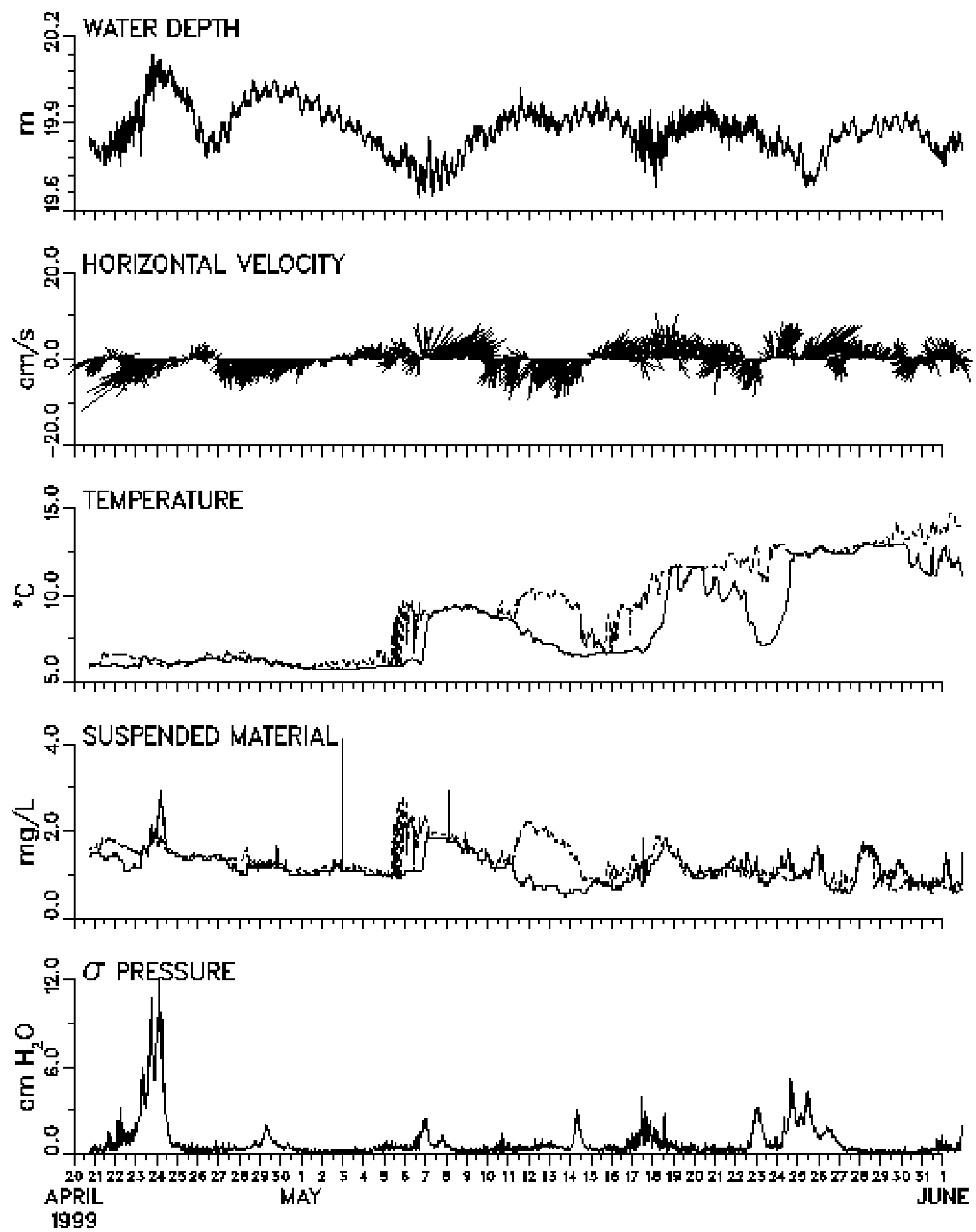


Figure 4b. As in Figure 1b for deployment 99-2.

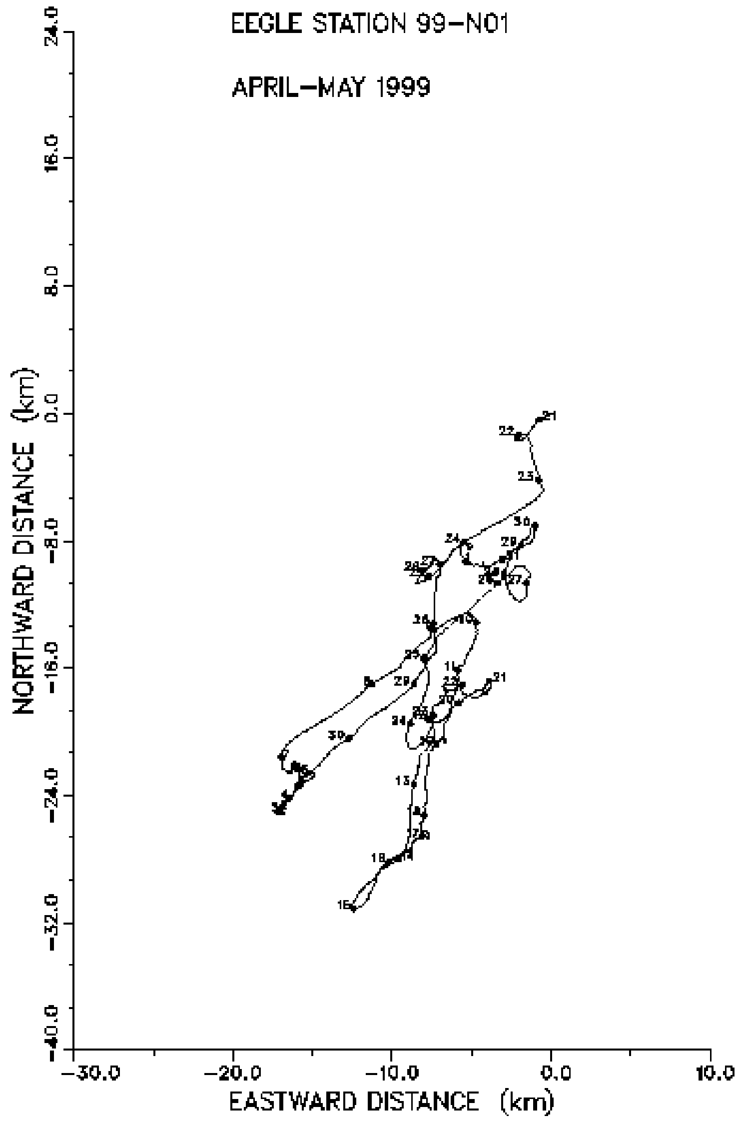


Figure 5a. As in Figure 1a for deployment 99-3.

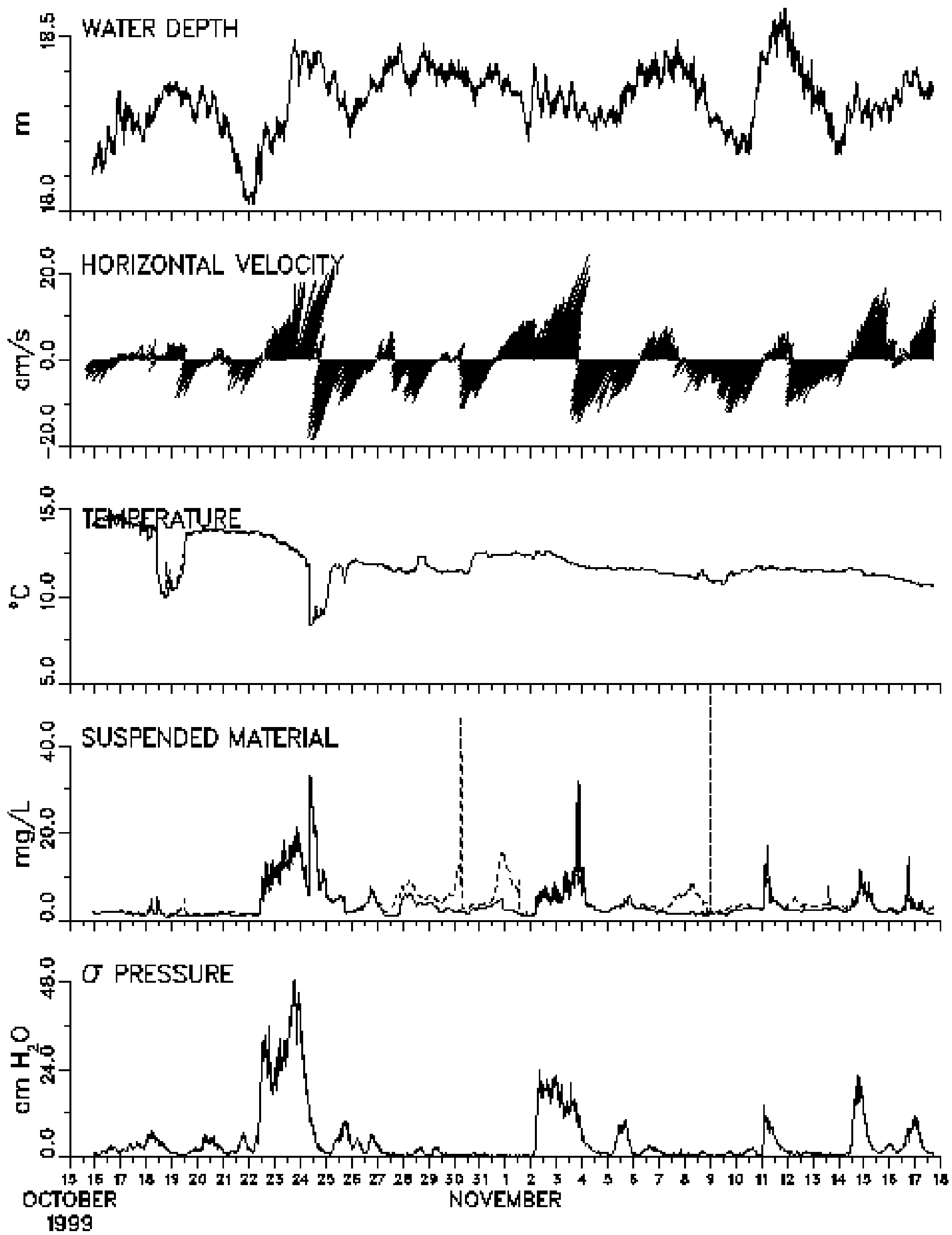


Figure 6a. As in Figure 1a for deployment 00-1.

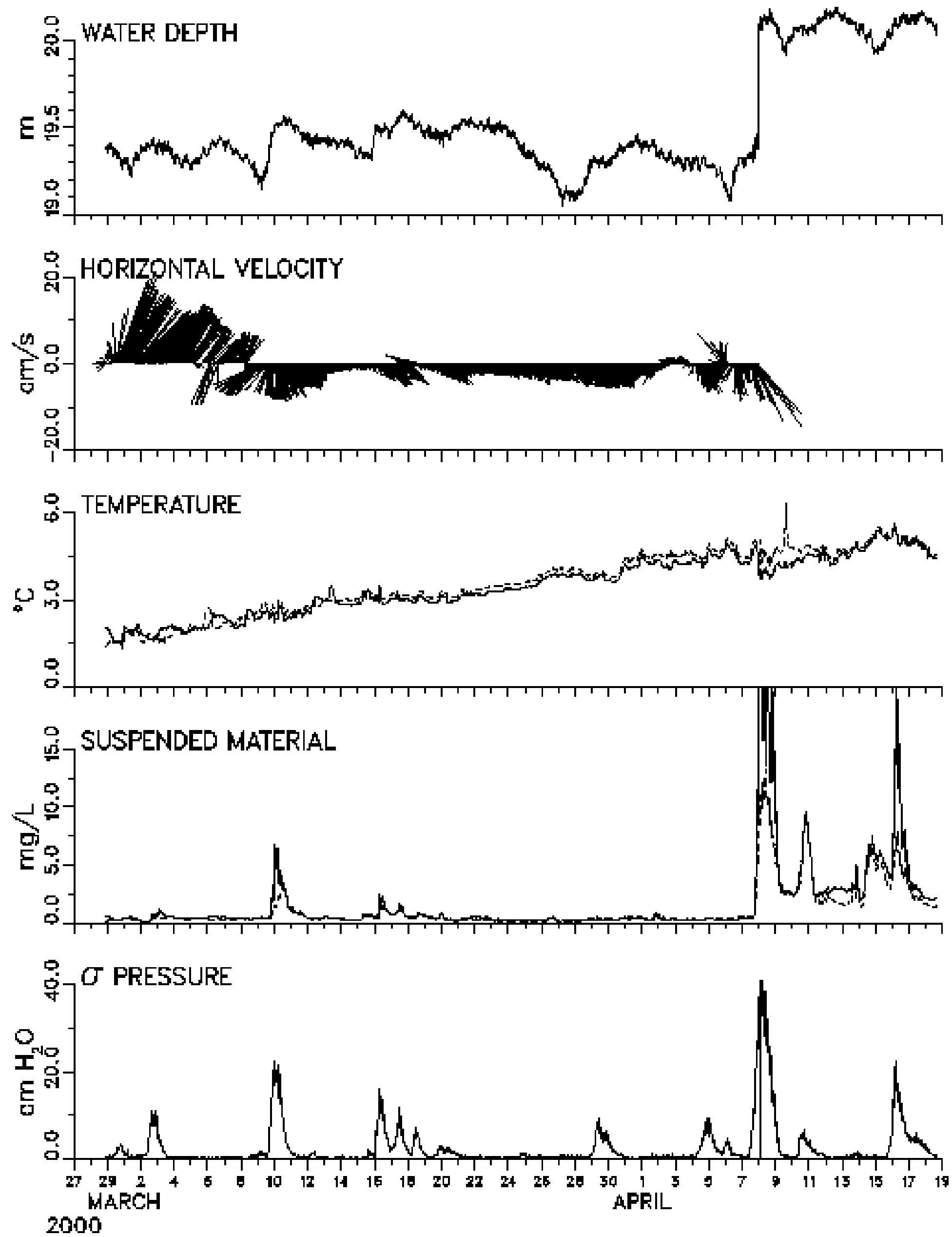
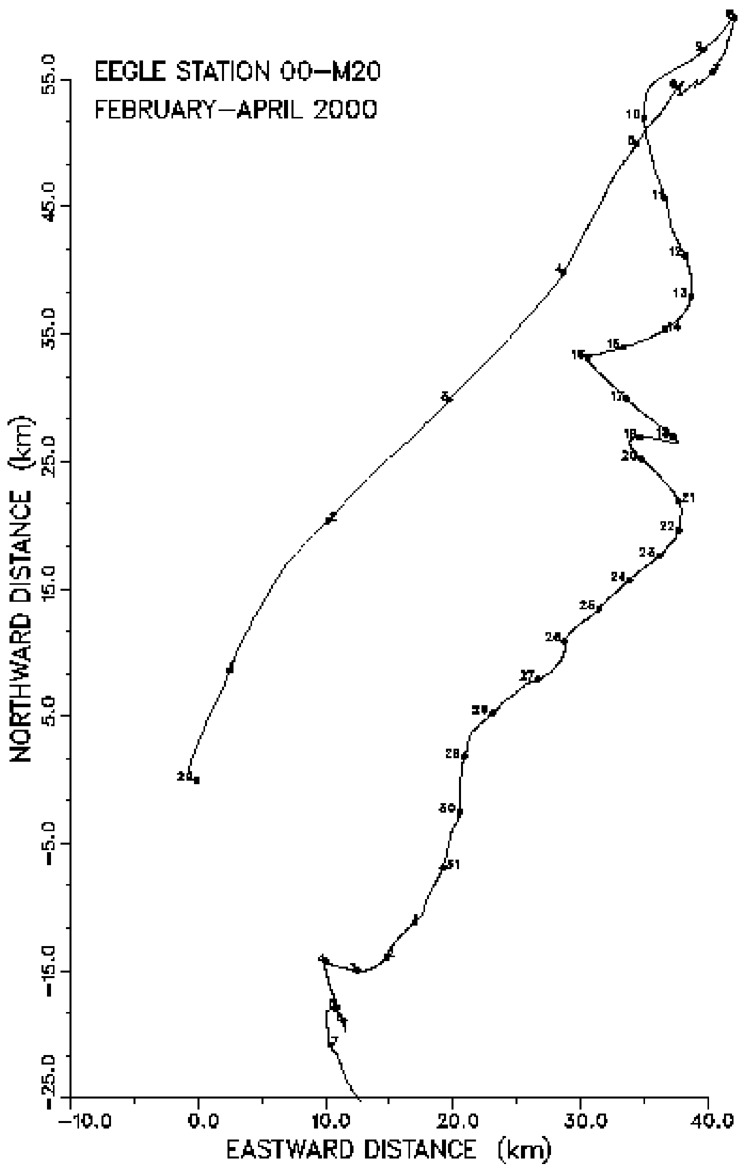


Figure 6b. As in Figure 1b for deployment 00-1.



Session #8
Contributed
Oral

LESHT, B.M. and HAWLEY, N., Environmental Research Division, Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439, and NOAA/GLERL, 2205 Commonwealth Blvd., Ann Arbor, MI 48105. **Empirical Modeling of Sediment Resuspension in the Great Lakes.**

Because of the importance of suspended sediments as carriers of nutrients and contaminants, many varieties of Great Lakes water quality models require sub-models that link the bottom sediments to the water column. These sub-models can be quite complicated, involving numerous sediment layers, several sediment size classes, and various parameterizations describing the time-dependent response of the sediment bed to the imposed hydrodynamic forcing (usually computed by other sub-models). Although impressive in formulation, these models are generally much more detailed and complex than are the available field data, and therefore the sub-model output cannot easily be compared with, or evaluated against, field observations. In an alternative approach, we have used observation-based, empirical analysis as the basis for developing methods for predicting observed sediment resuspension from relatively simple measures of hydrodynamic forcing. The methods have been quite successful in environments as different as Lake St. Clair and southern Lake Michigan. In this paper we will review some of the applications of empirical modeling of sediment resuspension and suggest ways of integrating the empirical models with the high-resolution, state-of-the-art water quality models that currently are under development.

Empirical Modeling of Sediment Resuspension in the Great Lakes

Barry M. Lesht[1] and Nathan Hawley[2]

[1]Environmental Research Division, Argonne National Laboratory

[2]NOAA/GLERL

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Compare detailed and simple modeling approaches with emphasis on field data

- Summary of the problem
- Brief overview of state-of-the-art models
  - SEDZL (*e.g.*, Lick et al. 1994, *JGLR, 20(4):599-612*)
  - Lou et al., 2000 (*JGR, 105(C3):6591-6610*)
- Description of field observations (tripods)
- Applications of simple observation-based models

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Sediment Transport Theory

- Moving water moves sediment.
- The response of the bottom sediments to an imposed flow will depend on:
  - The properties of the sediment
  - The nature of the flow

Modeling problems: What really is important? How do we characterize the sediments, the flows? What are the appropriate temporal and spatial scales to consider?

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Detailed sediment transport models

- Highly resolved spatially (*e.g.*, 5-km grid for SEDZL in Lake Michigan)
- Linked to detailed hydrodynamic models (may be three-dimensional or “quasi”-three dimensional)
- Multiple sediment grain size classes, multiple sediment layers
- Time-dependent sediment bed properties
- Complicated shear-stress formulations

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What about data?

- Sediment characteristics
  - Cohesive: grain size distribution, depth/time dependent porosity, settling velocity, organic composition, biological reworking
  - Non-cohesive: grain size distribution, porosity, settling velocity, critical shear stress, bottom roughness, bedforms

Even with careful laboratory results that may provide links between sediment type and response, how do we use them and evaluate their applications in the field?

Goals for Tripod Studies

- Long-term (weeks to months) in situ observations of near-bottom conditions
- Document frequency and intensity of sediment transport
- Determine simple, self-consistent model relating sediment transport to some easily measured (or modeled) feature of the flow
- Establish constraints on results of detailed modeling efforts; supplement laboratory studies

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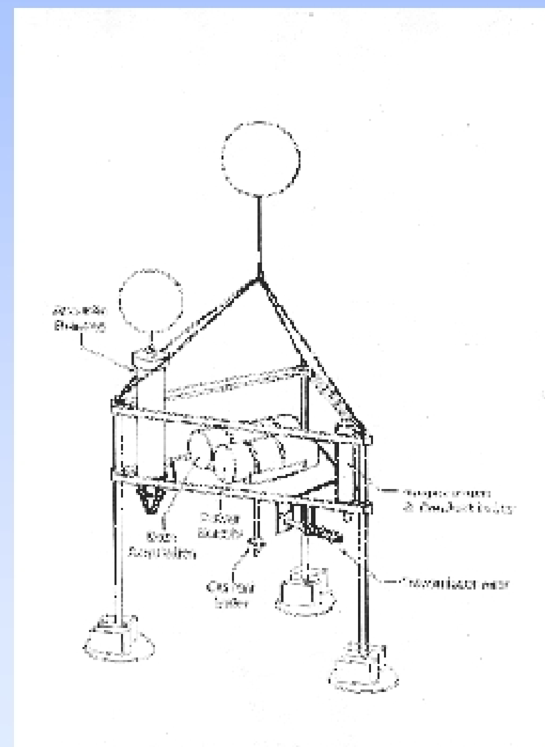
ANL Tripod is configured for making basic measurements.

Tripod is designed to gather basic information about the relationship between near-bottom flow and sediment transport rather than for detailed studies of the benthic boundary layer.

<u>Measurement</u>

Horizontal current velocity
Sediment concentration
Surface waves
Water temperature
Tripod orientation

Data acquisition - CSI
Sampling scheme - burst
Endurance - 45 to 60 days



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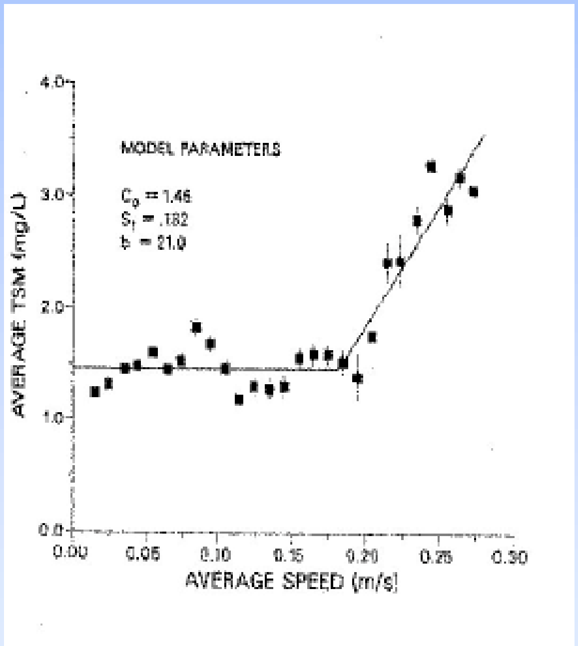
Simple model for near-bottom concentration



- Bottom sediment silty-sand, water depth 28m
- Average TSM binned by flow parameter (mean speed in this case).
- Assume model of the form

  $C(t) = Ca + b(U(t)\text{-}Uc); \; U(t) > Uc$

  $C(t) = Ca \qquad ; \; U(t) \leq Uc$
- Non-linear least squares fit to determine model parameters

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More involved (but still simple) model

- One-dimensional formulation in accord with measurements includes both resuspension and sedimentation fluxes
- Parameters may be determined by minimizing errors between model and observations
- Worked well in Lake St. Clair (Hawley and Lesht, 1992, *Limnol Oceanogr., 37(8):1720-1737*)

$$D\frac{dC}{dt} = R(U - U_c)^n - S(C - C_a) \qquad : U > U_c$$

$$D\frac{dC}{dt} = - S(C - C_a) \qquad : U \le U_c$$

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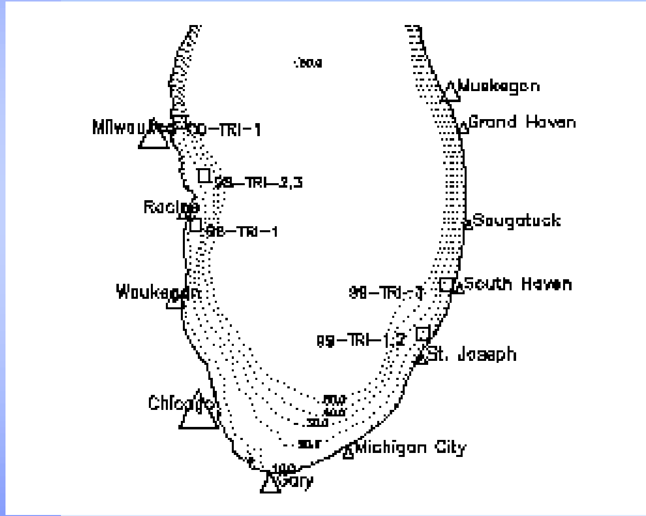
Argonne EEGLE Tripod Deployments



- 98-1 Wind Point, 15 m. 4/2/98 through 4/30/98, 1339 samples.
- 98-2 Oak Creek, 25 m. 7/23/98 through 8/24/98, 1539 samples
- 98-3 Oak Creek, 25 m. 10/28/98 through 12/1/98, 1631 samples
- 99-1 St. Joseph, 20 m. 2/25/99 through 4/19/99, no data.
- 99-2 St. Joseph, 20 m. 4/20/99 through 6/1/99, 2064 samples.
- 99-3 South Haven, 18 m. 10/15/99 through 11/17/99, 1575 samples.
- 00-1 Milwaukee, 20m. 2/28/00 through 4/18/00 2388 samples

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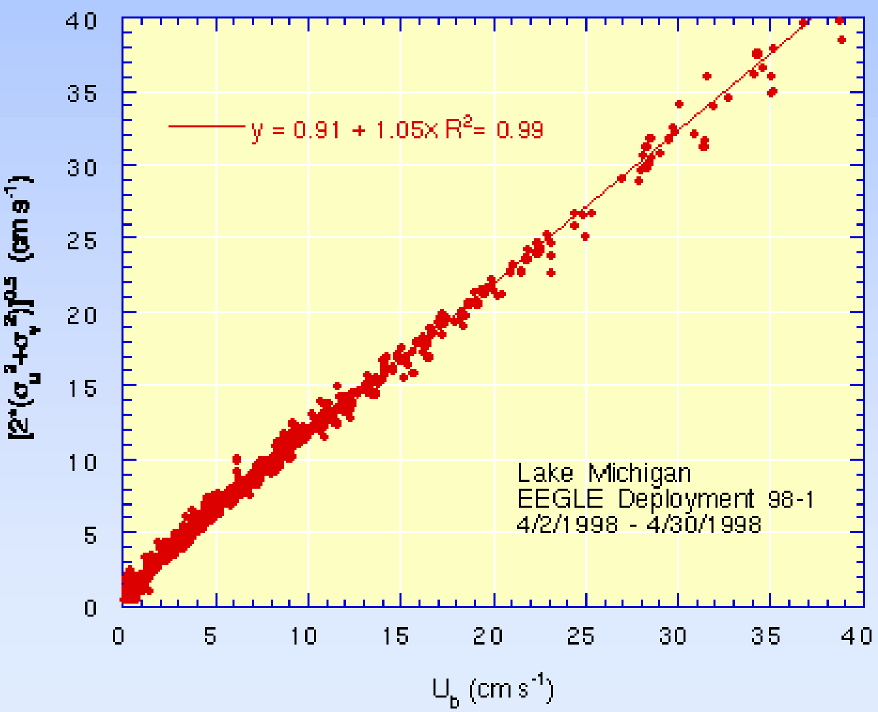
Comparison of current meter and pressure sensor fluctuations.



- Surface waves dominate near bottom current fluctuations.
- Linear wave theory is applicable.
- Current meter calibration is accurate..
- Pressure sensor sampling is adequate.

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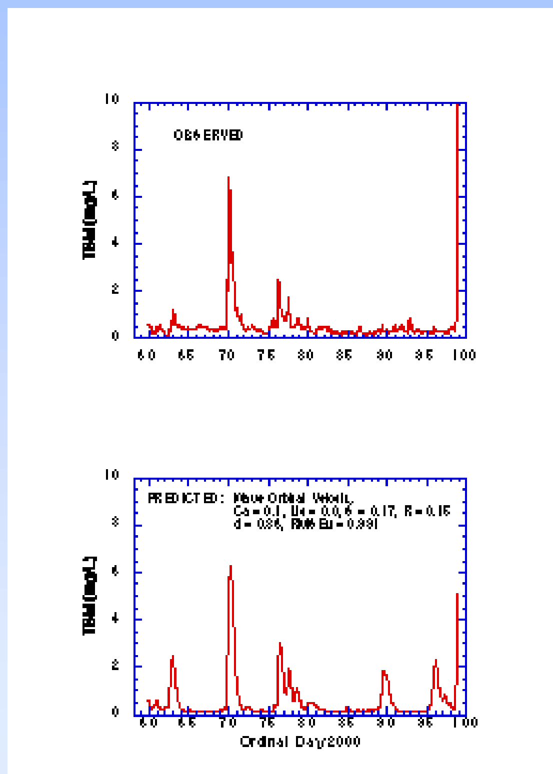
Simple model results for the spring 2000 deployment off Milwaukee.



- Model is forced by wave orbital velocity calculated from the pressure sensor.
- Model coefficients are determined by empirical fitting - not yet optimized.
- Statistic “d” represents the overall goodness of fit.
- Statistic “RMSEu” represents the percent of the root mean square error that is “unsystematic.”
- Bottom sediments sand over clay with large rocks.

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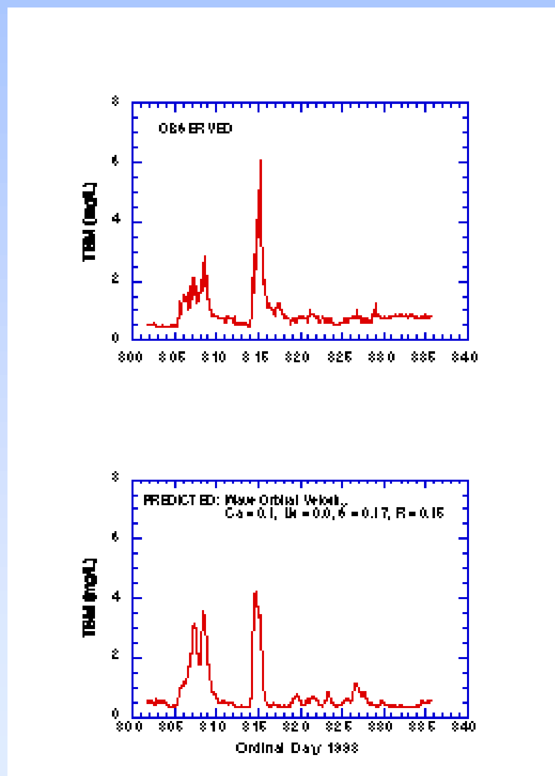
Simple model applied to fall 1998 deployment off Oak Creek.



- Model is forced with wave orbital velocity calculated from pressure data.
- Model coefficients are taken from the spring 2000 model.
- Bottom sediments silty clay.
- "d" = 0.807
- "RMSEu" = 0.892

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Preliminary EEGLE Modeling Results

- Resuspension is driven by surface waves; surface waves can be modeled from wind data.
- Empirical models using wave forcing can reproduce near bottom sediment concentration with good accuracy.
- Model parameters seem fairly robust (needs to be better tested)

Open question: In applications like this, how much "accuracy" can we afford to sacrifice for simplicity?

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Sediment resuspension and transport: notes from the trapping program

Brian J. Eadie[1], Margaret B. Lansing[1], Andy Winkelman[2], Brandon Giroux[2], and Craig Riley[2].
[1]NOAA-GLERL and [2]CILER.

Objectives:

1. quantify the distribution of particle concentrations and settling materials associated with episodic events and place them in an annual context, and
2. characterize the organic and nutrient composition of these materials for the purpose of estimating constituent fluxes

Approach:

- Moorings of sequencing sediment traps were deployed to examine mass flux events in the southeastern region of the lake and at offshore stations to seek both local and whole-lake responses.
- Moored transmissometers and sequencing water samplers were deployed in the southeastern region of the lake to measure suspended solids and provide samples for compositional analyses.

Results:

- Annual mass fluxes are strongly concentrated during the period of episodic events and there is lake-scale synchrony in the mass fluxes for major events

- Large amounts of resuspended coastal sediments, and associated constituents, get transported offshore to the middle of the lake. Estimates of mass and total phosphorus resuspension for the southern basin (table) are greater then total annual external loads.

Episodic Event Flux Calculations for the southern basin of Lake Michigan

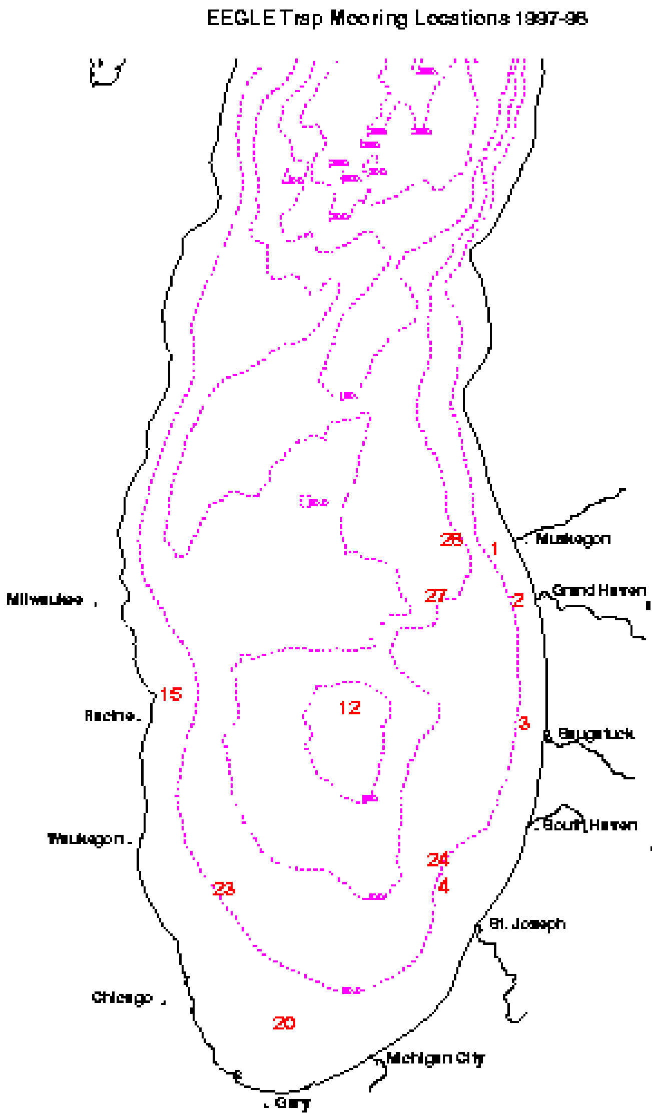
Interval	Calculation Basis	Mass (10^6 MT)	TP (10^3 MT)
Annual External Load	IJC (1995)	1	2 - 3
Day - April 10, 1996	Calibrated Satellite Image	1	1
Month - March, 1998	Model (Lou et al, 1999)	4	
Month - March, 1998	Traps	5	7
Seasonal - Unstratified, 1998	Traps	22	28
Seasonal - Unstratified average	Traps (1980-99; n=8)	13 ± 7	18 ± 8

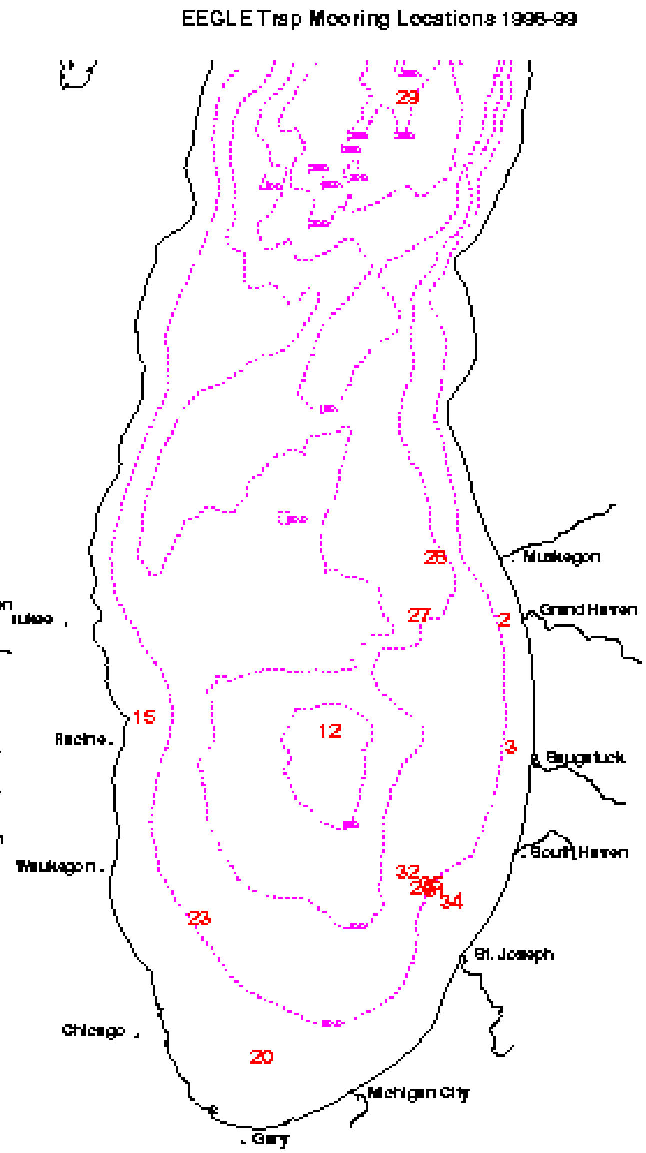
Lou, J., D.J. Schwab, and D. Beletsky (1999). Suspended sediment transport modeling in Lake Michigan. Proceedings of the Canadian Coastal Conference.

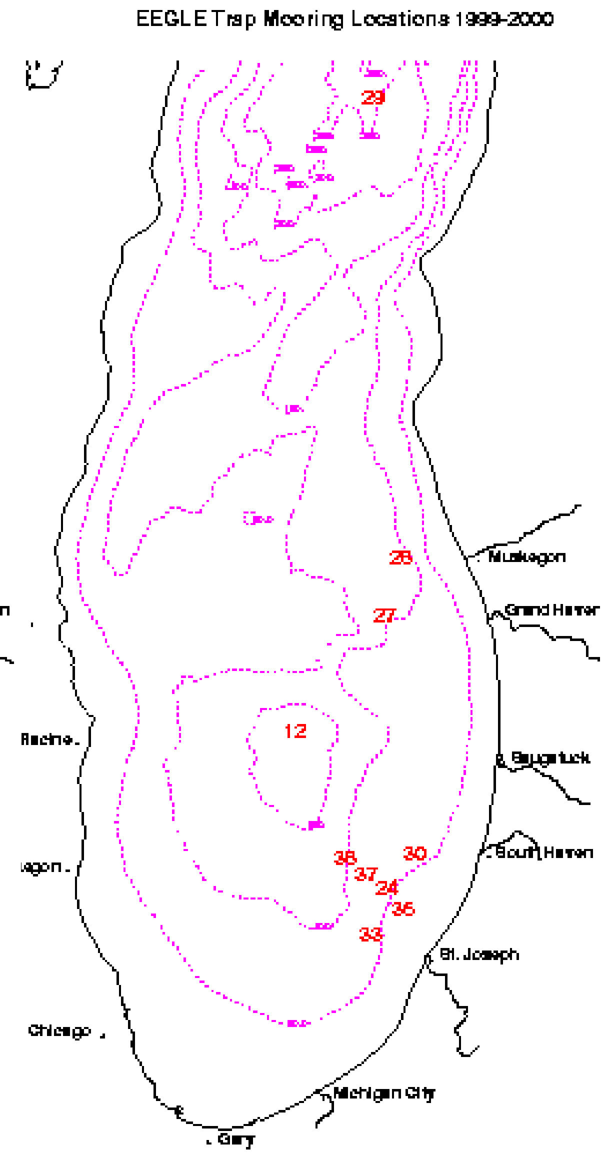
IJC (1995). State of the Great Lakes.

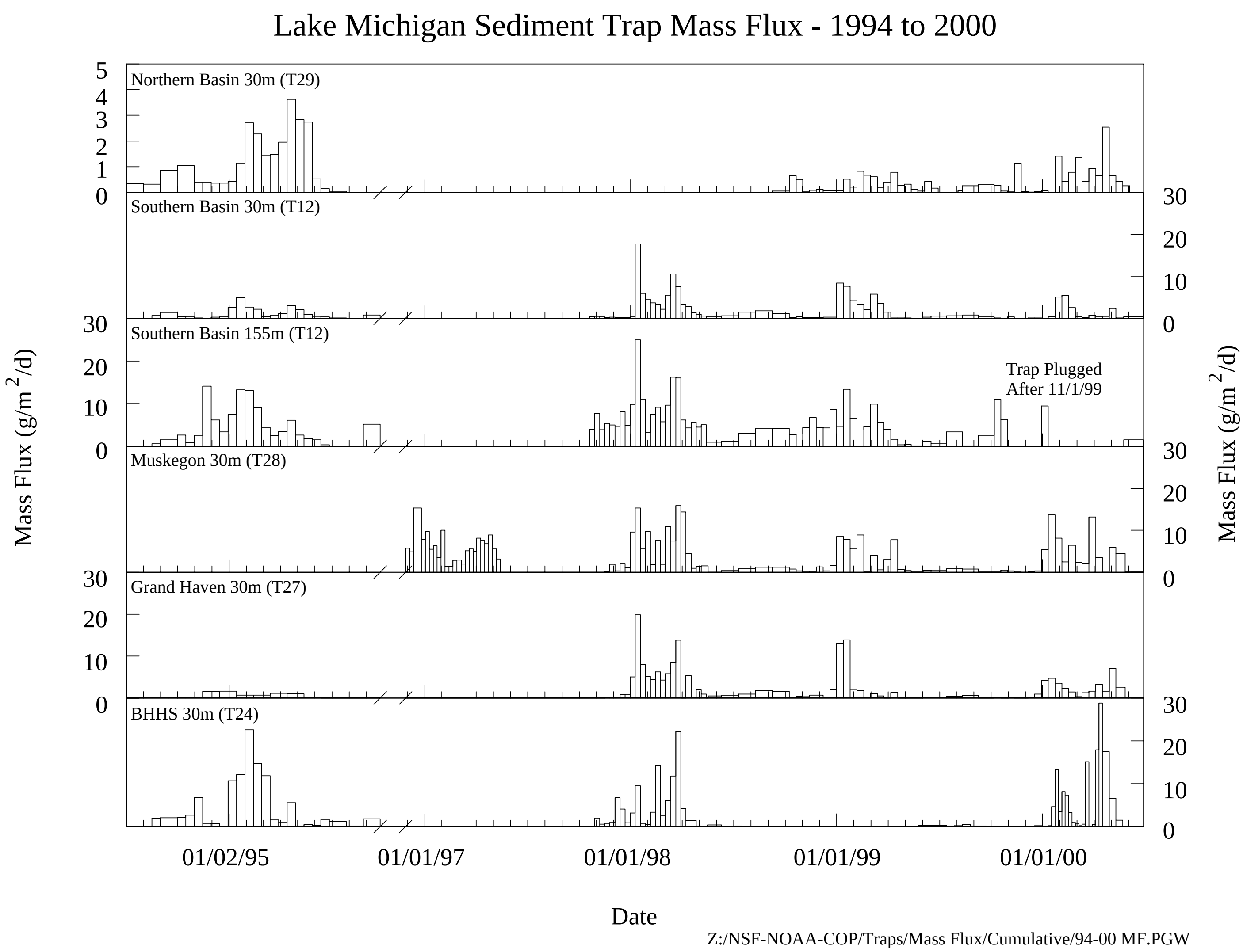
Collaborators

Robbins (transport into a depositional region), Johengen (nutrient fluxes), Schwab and Lou (resuspension and transport), Edgington, Klump, and Waples (coastal resuspension), Hornbuckle (HOC resuspension), Kerfoot (resting eggs), and Gardner (nitrogen recycling).


EEGLE Trap Mooring Locations 1997-98
Muskegon
Grand Haven
Milwaukee
Racine
Saugatuck
South Haven
Waukegan
St. Joseph
Chicago
Michigan City
Gary
28
1
27
2
15
12
3
24
4
23
20

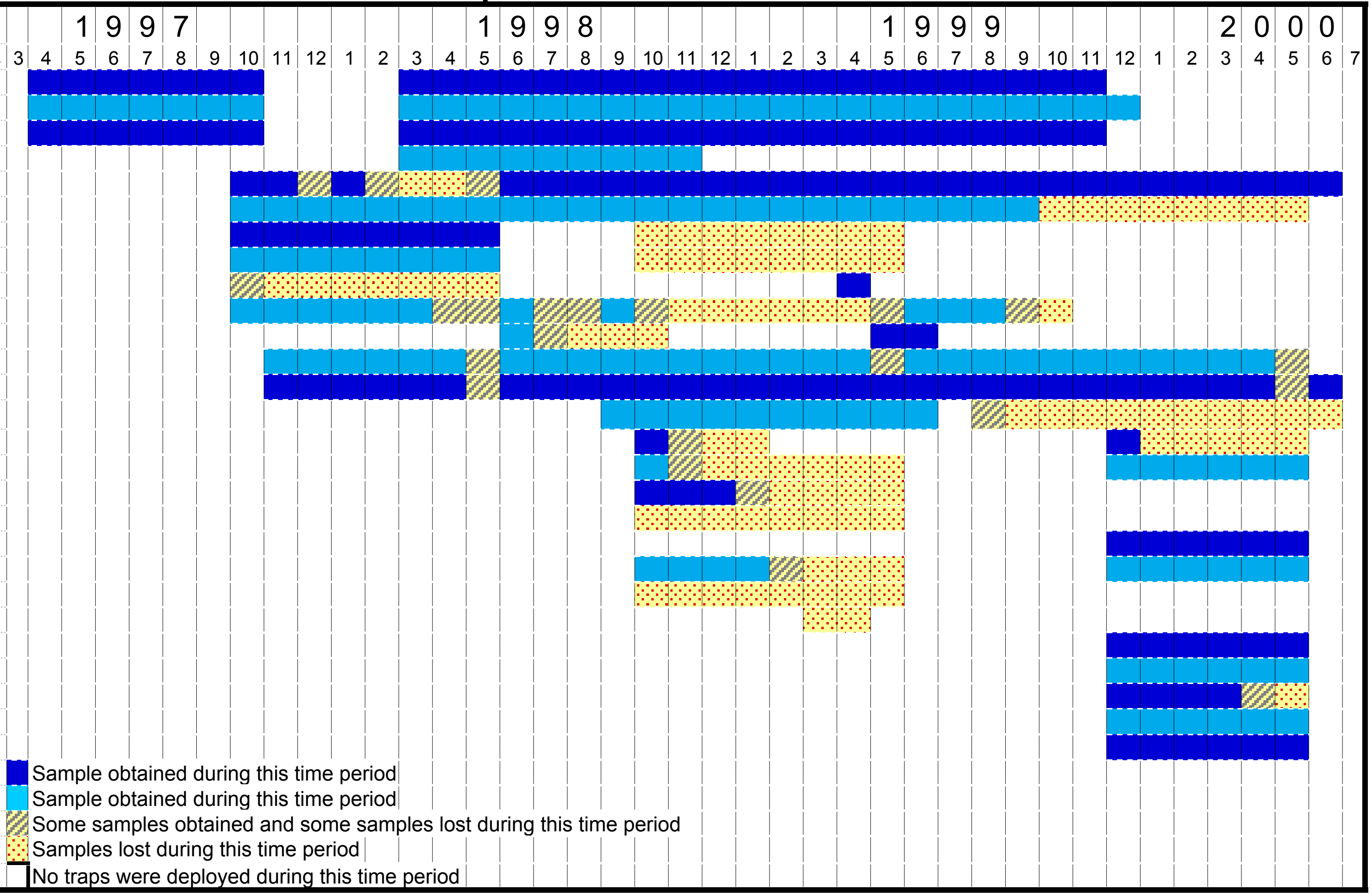

EEGLE Trap Mooring Locations 1998-99
29
Muskegon
Grand Haven
Racine
Saugatuck
South Haven
Waukegan
St. Joseph
Chicago
Michigan City
Gary
28
27
2
15
12
3
32
34
23
20


EEGLE Trap Mooring Locations 1999-2000
29
Muskegon
Grand Haven
Racine
Saugatuck
South Haven
St. Joseph
Chicago
Michigan City
Gary
28
27
12
38
30
37
24
35
33


Lake Michigan Sediment Trap Mass Flux - 1994 to 2000
Northern Basin 30m (T29)
Southern Basin 30m (T12)
Southern Basin 155m (T12)
Trap Plugged
After 11/1/99
Muskegon 30m (T28)
Grand Haven 30m (T27)
BHHS 30m (T24)
Mass Flux (g/m 2 /d)
01/02/95
01/01/97
01/01/98
01/01/99
01/01/00
Date
Z:/NSF-NOAA-COP/Traps/Mass Flux/Cumulative/94-00 MF.PGW

EEGLE: Trap Collection Success

Station #	Trap Z (m)	# of samples
1	15/30/45	66
2	15/30/45	65
3	15/30/45	39
4	15/30/45	34
12	30	84
12	155	54
15	12	23
20	12	23
23	12	3
24	30	59
24	50	5
27	30	65
28	30	68
29	30	23
30	30	5
30	49	25
31	39	7
32	65	0
33	30	23
33	60	33
34	30	0
35	45	0
36	30	23
37	30	23
37	71	20
38	30	23
38	95	23
total:		total:
27		816



A STUDY OF ORGANIC CONTAMINANTS IN AIR AND WATER IN CONJUNCTION WITH EPISODIC EVENTS – GREAT LAKES EXPERIMENT

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Overview:

This study examines the effect of large-scale resuspension on the cycling of persistent organic pollutants (POPs) in southern Lake Michigan. During eight sampling cruises between 1998 and 2000, we have collected over 74 water samples and more than 61 air samples. In addition, Eadie and Lansing have provided sediment from 8 sequencing settling traps and Klump and Waples have provided surficial sediment from the western coastal region. All samples are analyzed for a suite of POPs including 98 PCB congeners, 25 polycyclic aromatic hydrocarbons (PAHs) and 20 chlorinated pesticides.

In June 2000, a paper was submitted to *Environmental Science & Technology* (attached) the paper reports results from the 1998 field season. In this paper, we report PCB and PAH concentrations in air, water and settling sediments and chemical fluxes for the 1998 resuspension event. In that paper, we examined and affirmed Hypothesis 1, below:

Hypotheses:

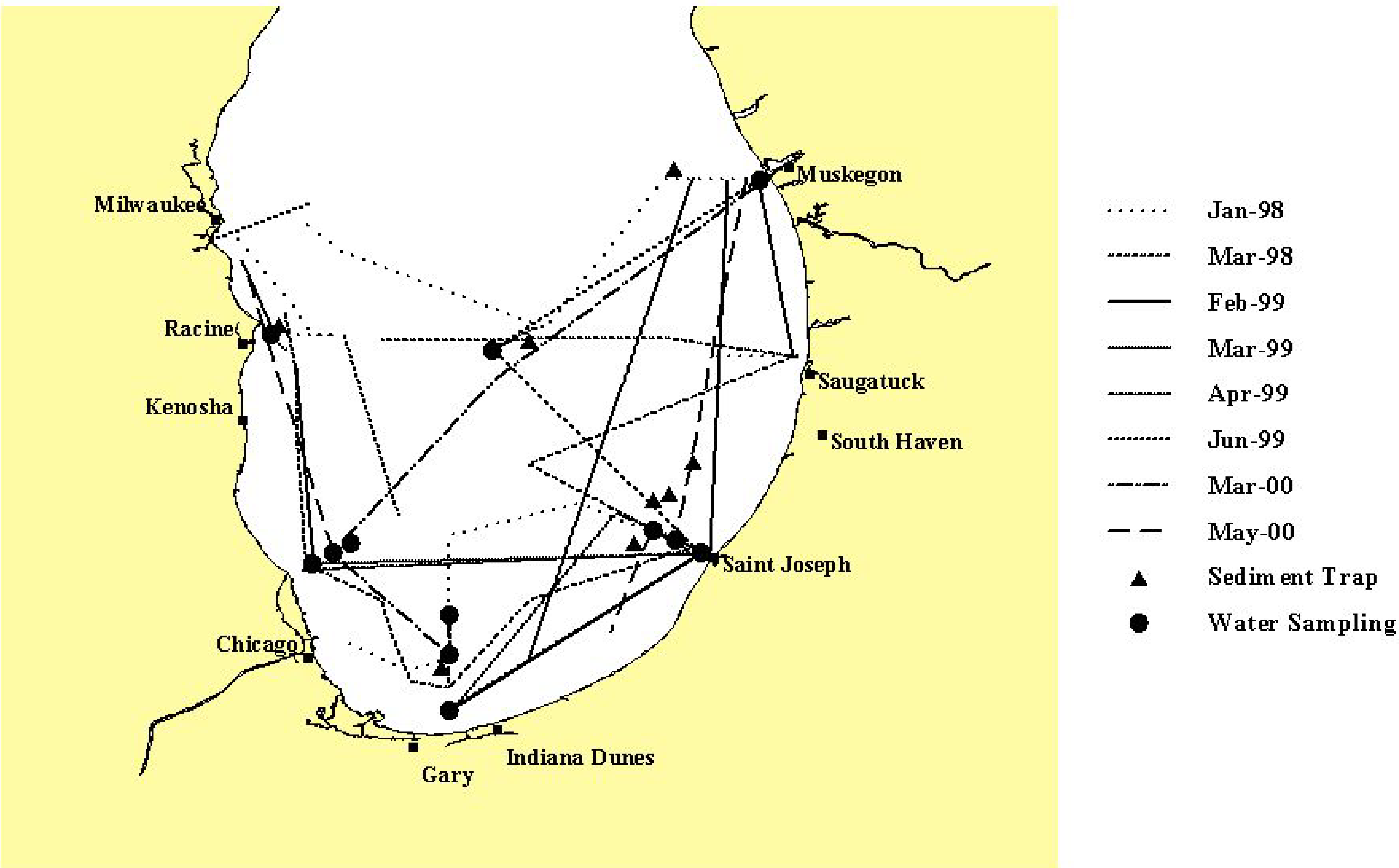
Large scale resuspension in southern Lake Michigan causes a reduction in dissolved phase concentration of persistent organic pollutants. We hypothesize that this reduction induces atmospheric deposition of gas-phase POPs. We further hypothesize that this induced load is a significant portion of the total atmospheric load of PCBs and PAHs delivered to Lake Michigan from the atmosphere.
Resuspension of contaminated sediment near the Chicago-Gary region causes an increase in particulate associate POPs in the south-east coastal region. We hypothesize that most of this material does not desorb from the particles. We further hypothesize that these particles fall through the water column and are deposited in the deep basin sediment accumulation zones.

Current Activities:

Air, water and sediment samples are currently being analyzed for the target chemicals. Chemical analyses expected to conclude in spring 2001. Modeling work is on-going through 2002 (funds permitting – this project is funded through 2000 by GLNPO/EPA).

Sample description:

Media	Analyses	Status: Extraction	Status: analytical
Vapor-phase air(hi-vol)	POPs	Completed	Completed
Particulate phase air (hi-vol)	POPs	Completed	Incomplete
Aerosol size distributions (MOUDI)	Mass concentration of particles by size	NA	Incomplete
Dissolved phase water	POPs	Completed	Incomplete
Particulate phase water	POPS	Incomplete	Incomplete
Sediment trap material	POPs	Complete	Incomplete
Surficial Sediment	POPs	Incomplete	Complete



Milwaukee
Racine
Kenosha
Chicago
Gary
Indiana Dunes
Saint Joseph
South Haven
Saugatuck
Muskegon
Jan-98
Mar-98
Feb-99
Mar-99
Apr-99
Jun-99
Mar-00
May-00
Sediment Trap
Water Sampling

Sediment resuspension and transport: radionuclide tracer studies

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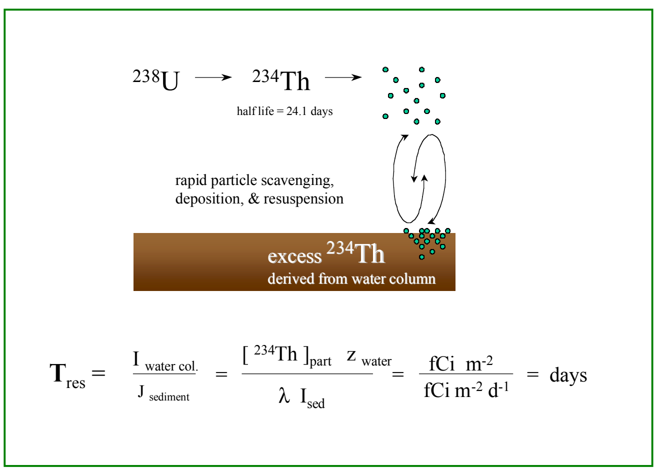
[1]University of Wisconsin-Milwaukee and [2]Argonne National Laboratory

Objectives:
1. investigate the dynamics of resuspension by quantifying changing particle residence times in both the water and the sediments of the nearshore plume zone of the southern basin
2. estimate alongshore mass transport rates for these particles
3. couple transport rates with particle composition changes to estimate transformation rates

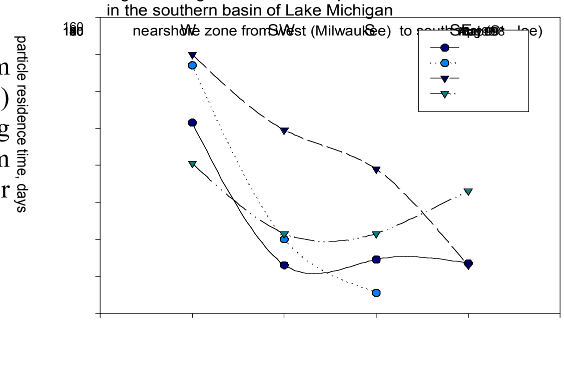
Approach:
- Inventories of particulate and dissolved Th-234 (1/2 life = 24 d), a particle reactive, naturally occurring radionuclide, and its parent, U-238, have been measured in the water column and sediments of the nearshore region of southern Lake Michigan from Milwaukee to St. Joe (1998-1999)
- Water column and sediment inventories were also measured on a cross margin transect from 10 to 40 meters off Milwaukee for three 10 day time series (Mar-May 2000), along with simultaneous sediment trap and tripod deployments and CTD casts.
- Suspended sediment concentrations and activities of particulate and dissolved Th-234 were measured on a daily basis from late Jan 2000 to late May 2000 from water taken from the Milwaukee water filtration plant (MWFP) intake at 20 meters, ancillary data on particle size distribution, turbidity and conductivity were collected by the MWFP.



- The basic approach relies on the fact that the parent isotope U-238 behaves as a conservative, non-reactive element in lake water (i.e. is in solution) with a relatively constant concentration and a very long half-life. Its daughter, Th-234, is particle reactive and short-lived (24 day half-life). Rapidly scavenged by particles in the lake, excess Th-234 generated in the overlying water column can be detected on the bottom only if particle settling rates are relatively rapid. Hence the depletion or the enrichment of Th-234 in the water or on the bottom can be used to calculate relevant short term particle residence times. One such type of calculation is shown in the adjoining figure.
- Horizontal transport and particle movement may also be estimated from alongshore focusing and enrichment of excess Th-234.

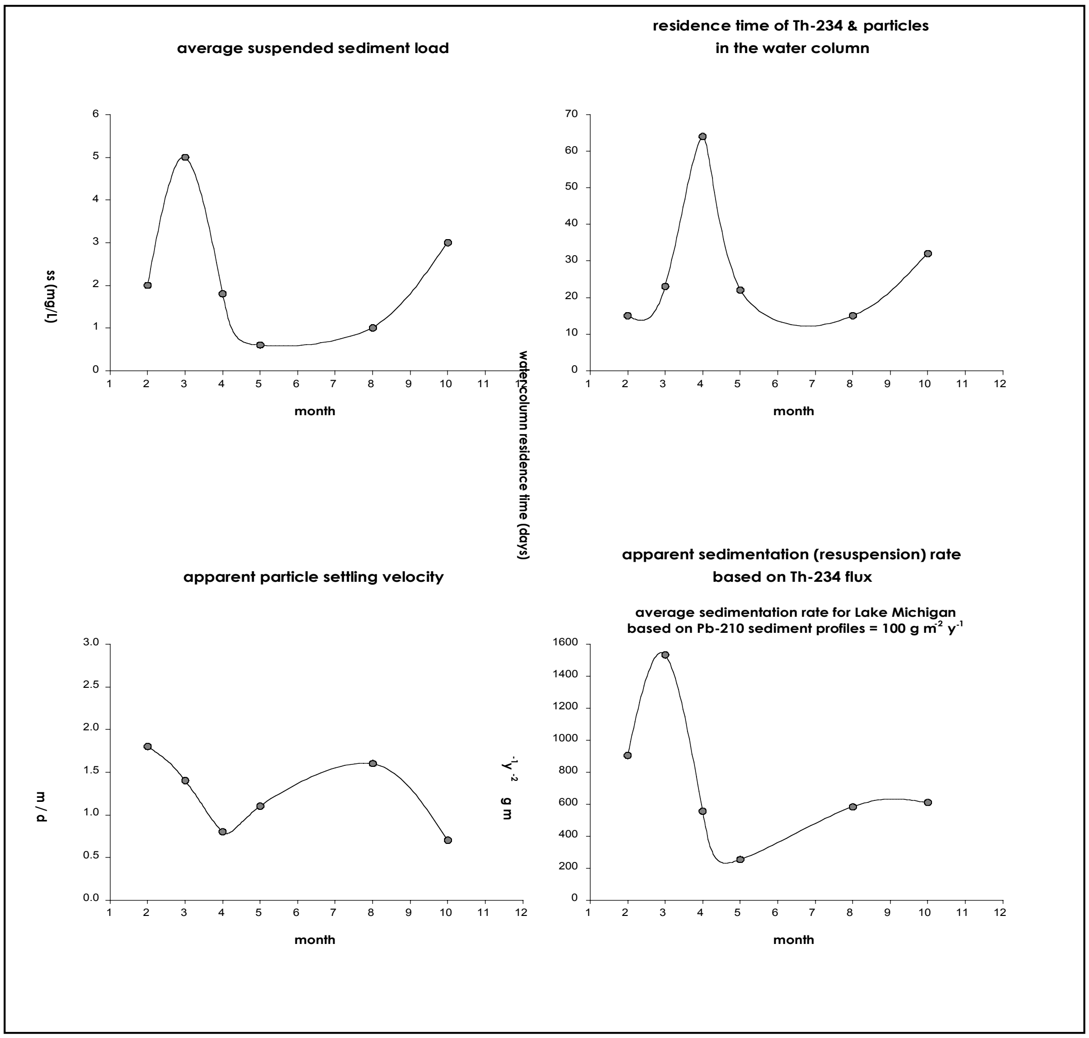
Results:
- In general, particle residence times determined from sediment inventories (calculation shown above) decrease in a counter-clockwise trend, in keeping with the general concept of sediment transport from sources on the western side of the basin to the major depositional sink region off of St. Joe (fig. 2).

Fig. 2. Alongshore variation in particle residence times in the southern basin of Lake Michigan



- Temporal variations in nearshore (10 m to 40 m) particle behavior show a familiar bimodal increase in the suspended particle load, with the highest suspended sediment concentrations occurring in March. The "instantaneous" residence time of particles in the water column generally fell between 10 and 20 days, with exceptions occurring during the months of April (64 days) and October (32 days). One hypothesis is that increased residence times may be associated with increased diatom abundance associated with spring and fall phytoplankton bloomes. Particle settling velocities varied by a factor of 3 from 0.7 to 1.8 meters per day. "Annual" resuspension rates for each month were calculated as the product of the particle settling velocity and the suspended sediment concentration. Resuspension rates peaked during the month of March at > 4 g m^{-2} d^{-1}, nearly two orders of magnitude higher than average net accumulation rate in the lake. (Figure 3).

Figure 3. Seasonal particle dynamics based upon water column measurements of Th-234 in southern Lake Michigan



Collaborators:
Eadie (sediment trapping); Robbins (transport into a depositional zone); Lesht (tripod measurements of hydrodynamics); Hornbuckle (HOC resuspension); Schwab (modeling); Milwaukee Water Filtration Plant (continuous monitoring).

Role of Episodic Events in Long-Term Accumulation of Sediments

John A. Robbins[1], D. N. Edgington[2], N. R. Morehead[1], R. W. Rood[3], B. J. Eadie[1] and K. A. Orlandini[4]. [1]NOAA-GLERL, [2]GLWI, [3]CILER,[4]ANL.

Objective:

- Assess the role of episodic events in accumulation and focusing (winnowing) of sediments in Lake Michigan.

Approach:

- Collect sediment cores with high spatial resolution within the principal high deposition (HIDEP) area in southeastern Lake Michigan situated about 10km offshore from St. Joseph near or within a convergence zone (Figure 1).

- Core a 30x40 km array of HIDEP sites on several occasions before and after late winter/early spring episodic re-suspension events (cruises in Sept. and Nov.1998, Feb., April and June 1999).

- Determine total inventories of long-lived fallout ^{137}Cs ($t_{1/2}$=30 years) as a measure of long-term sediment accumulation patterns.

- Determine total inventories of short-lived atmospherically delivered ^{7}Be ($t_{1/2}$= 53 days) and water column produced ^{234}Th ($t_{1/2}$=24 days) as measures of short-term sediment deposition patterns.

Results:

- The total inventory of Cs-137 (using data from all cruises) is highly focused within the HIDEP area (Figure 2) and looks very much like the long-term pattern of post-glacial sediment accumulation in this area.

- Total ^{7}Be inventories during the pre-event periods (Sept. 1998 and Feb. 1999) show little variability within the HIDEP area and, if anything, are lower in the most focused regions according to the ^{137}Cs data (Figure 3).

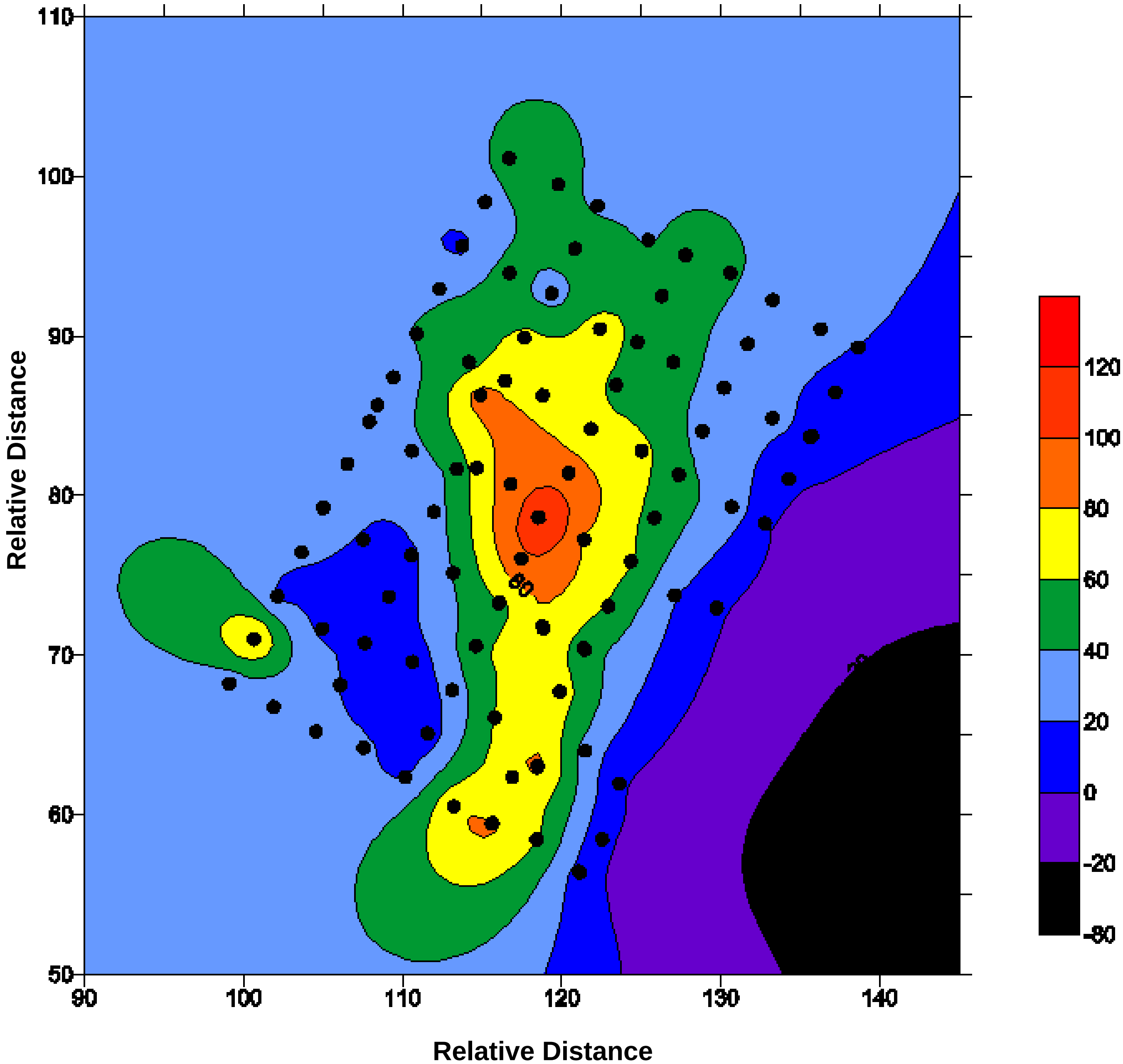
- During the post-event periods (April and June, 1999) ^{7}Be tends to be focused more like Cs-137, especially by June (Figure 3). The pattern in June developed so long after late winter that it is likely due to processes other than February/March episodic re-suspension events.

- The June inventory of ^{234}Th (Figure 4) was essentially unrelated to long-term sediment focusing and tended to be far higher toward in shallower water than expected from its production in overlying water.

Collaborators

J. V. Klump and J. Waples (coastal resuspension).

EEGLE Cs-137 Inventories (dpm/cm2)
Lake Michigan High Deposition Area

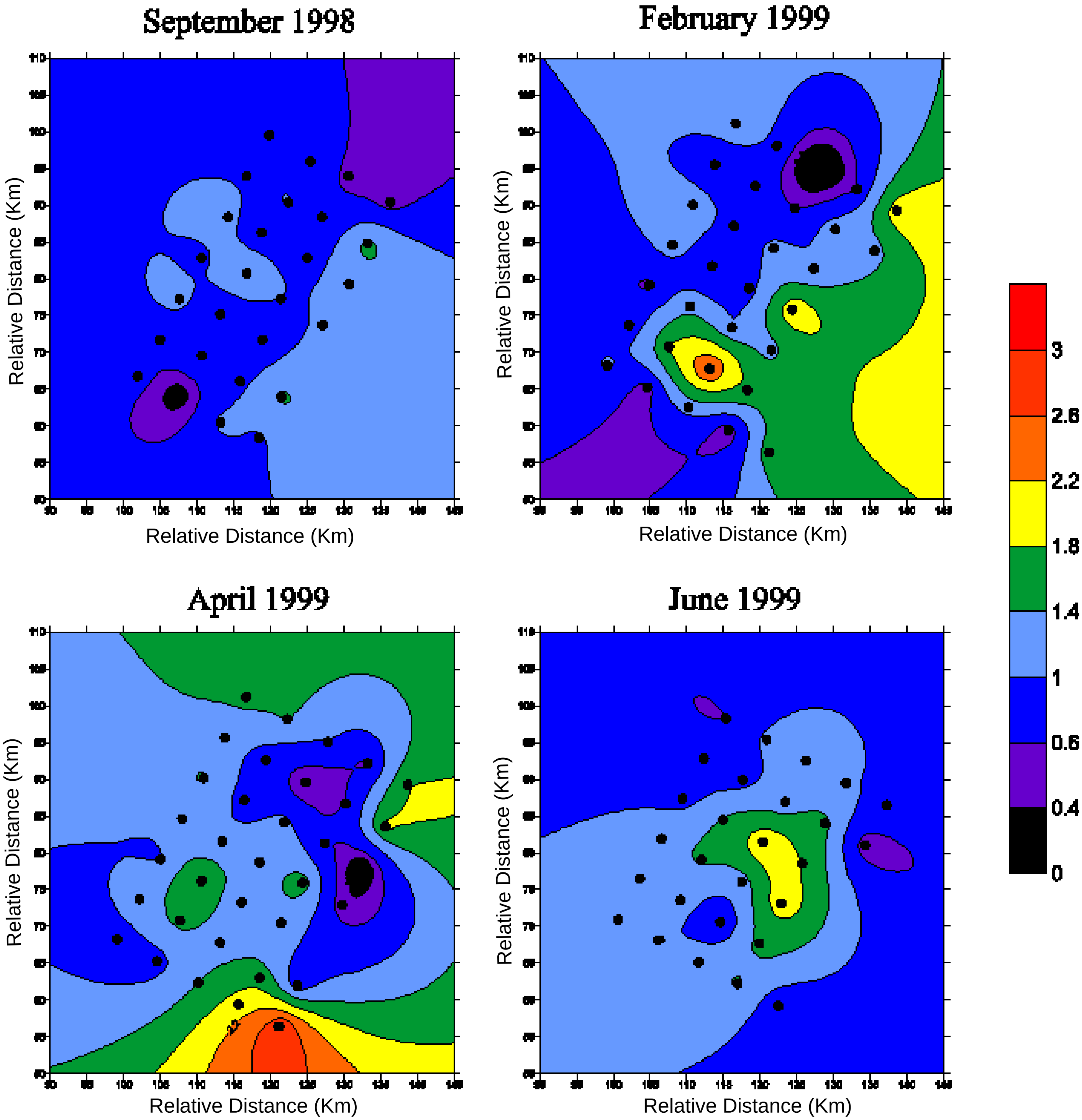


Inventory of Cs-137 (1/2=30.2 yr). Particles labeled by this radionuclide are strongly focused toward the center of the HI-DEP area in accord with the pattern of accumulation of postglacial sediments (Waukegan Member).

EEGLE Be-7 Inventories (dpm/cm2)

Lake Michigan High Deposition Area

be7inv.srf

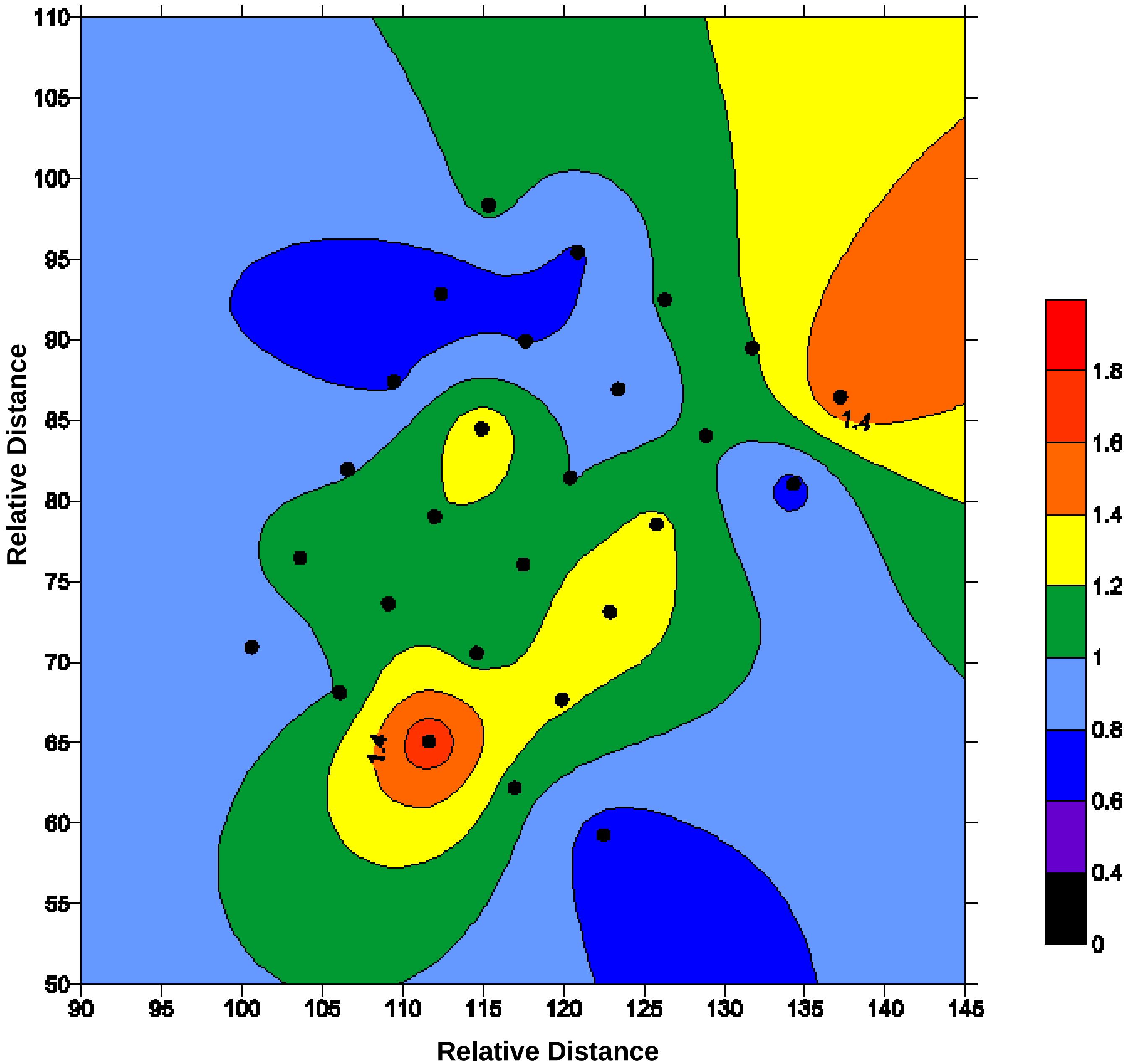


Inventories of Be-7 (1/2=53 da) at four different times. In September 1998, the radionuclide was not strongly focused in the HI-DEP area. In February 1999, before the occurrence of primary episodic resuspension events,there is preferential accumulation of Be-7 toward the southwestern end of the coring grid. In April 1999, well after such events, the pattern is comparable with no indication of focusing toward the HI-DEP center. By June, the pattern, now more in accord with the accumulation of Cs-137 and postglacial sediments, must have been produced by processes other than late winter-early spring resuspension events.

EEGLE Thorium-234 Inventories (dpm/cm2)

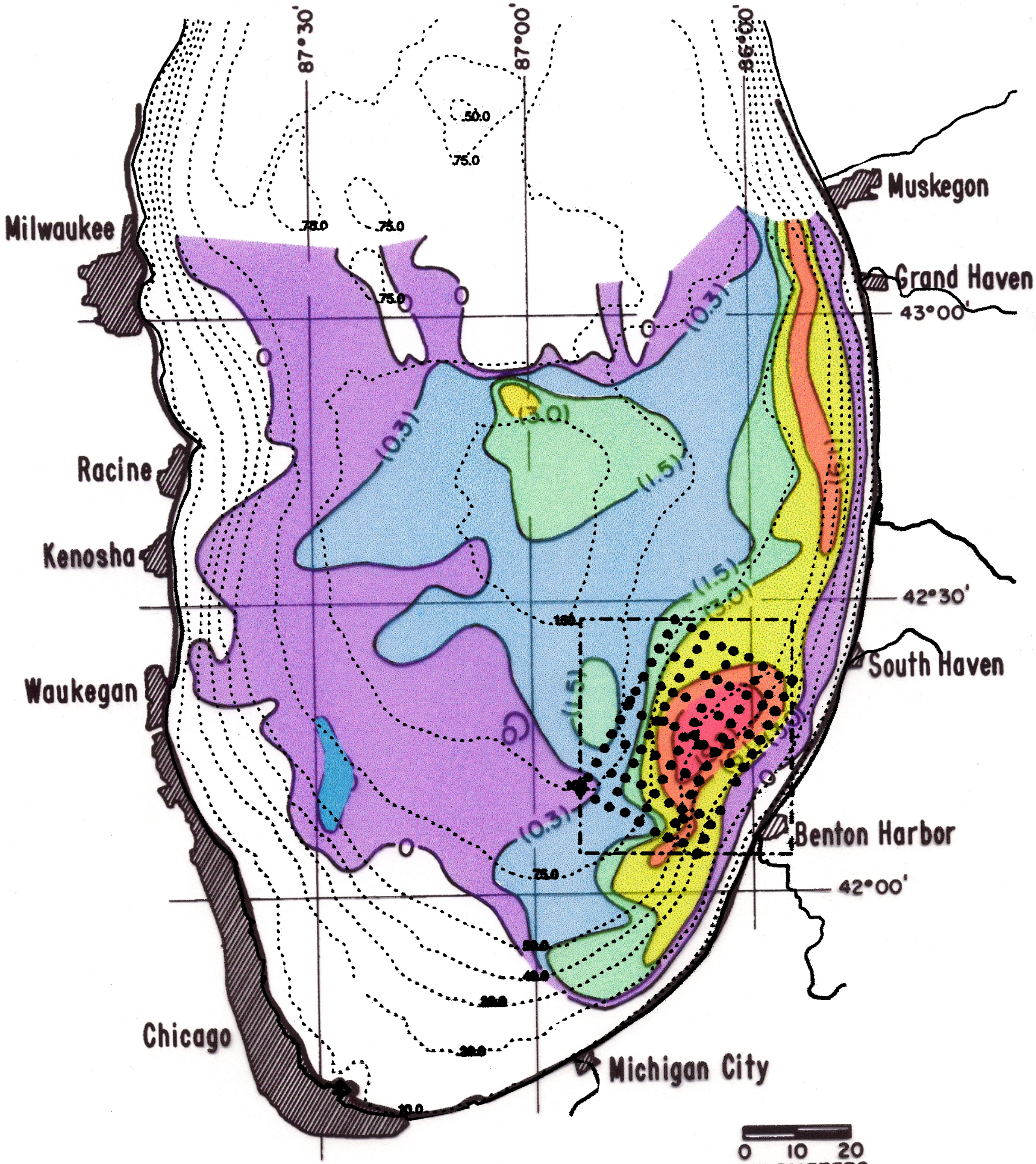
Lake Michigan High Depostition Area

June 1999



Inventory of Th-234 (t1/2=24 da). This radionuclide has accumulated preferentially toward the inshore regions of the HI-DEP area. The pattern bears little resemblance to the long term patterns of Cs-137 and sediment accumulation.

EEGLE Box Core Locations



Thickness (meters) of the Waukegan Member in Southern Lake Michigan
(IL State Geo. Survey, 1972 adapted).

Development of a coupled sediment transport and re-suspension model for Lake - Michigan

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To study cross-margin transport in southern Lake Michigan during episodic events and to identify transient and permanent particle sinks along the path of suspended material plumes, a multi-grain, multi-source sediment transport formulation has been considered. Five control volumes with an 18 km width and with variable lengths were selected along the western and the southern shores of the Lake Michigan and three representative grain sizes, one from each sediment size class (sand silt, clay) were assigned to the bottom of the Lake and to each control volume. Calculations were performed using the Coupled Marine Prediction System developed at the Ohio State University. CO.MA.P.S. consists of the WAM wind wave model, the CH3D hydrodynamic circulation model, the CH3D-SED sediment transport and re-suspension model and the BBLM bottom boundary layer model. All four models are fully coupled and parallel versions of the codes are used to minimize the CPU and the real time requirements. Four diagnostic components were considered during the analysis which in increasing degree of complexity are as follows: a) model runs with no waves and no shore erosion terms included, b) model runs with waves but erosion terms are not included, c) model runs with shore erosion terms but waves are not included , and d) model runs with waves and erosion terms included. The scope of such an analysis is to evaluate the impact of the diagnostic components on the transport and the distribution of the suspended sediment classes. The fully coupled model was run on a 2-Km spatial grid for the test period from March 1st , 1998 to March 31st, 1998. Model outputs include: 3-D velocity, temperature and concentration fields, vertically integrated velocities and grain size distributions at the Lake bottom, from which hourly trajectory maps are generated.